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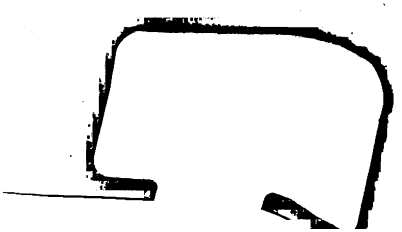

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Carpentry and Contracting

A Practical Reference Work on

CARPENTRY, BUILDING SUPERINTENDENCE, CONTRACTING, SPECIFICATIONS, ESTIMATING, BUILDING LAWS AND CODE, UNDERWRITERS' REQUIREMENTS, HEATING, VENTILATION, PIPE FITTING, PLUMBING, ARCHITECTURAL DRAWING, BLUEPRINT READING, ETC.

Prepared by a Staff of

ARCHITECTS, CARPENTERS, CONTRACTORS, AND BUILDING EXPERTS OF THE HIGHEST PROFESSIONAL STANDING

Illustrated with over Fifteen Hundred Illustrations

FIVE VOLUMES

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Grateful acknowledgment is here made also for the invaluable cooperation of the foremost architects, engineers, and builders in making these volumes thoroughly representative of the very best and latest practice in the design and construction of buildings; also for valuable drawings and data, suggestions, criticisms, and other courtesies.

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THE UNITARIAN-UNIVERSALIST MEETING HOUSE AT SUMMIT, NEW JERSEY
Joy Wheeler Dow, Architect, Summit, New Jersey
For details of portico see reverse side of page

DETAILS OF PORTICO OF UNITARIAN-UNIVERSALIST MEETING HOUSE AT SUMMIT, NEW JERSEY

Joy Wheeler Dow, Architect, Summit, New Jersey

For full exterior view of church, see reverse side of page

Foreword

THE building industry is today one of our most important and permanent institutions. Every new family unit must find a dwelling place, every new industry must be properly housed in order to do its work without hindrance from the weather. But with this development have come complications never dreamed of by our forefathers. In former years, every carpenter was a builder and he did very well for he confined himself to simple jobs—in fact there were none but simple jobs. There were then no complications with plumbing, gas and water fitting, heating, electric wiring, etc. There were no city ordinances to comply with, no building restrictions to be acquainted with. The laws regarding property rights, labor, etc., were simple, and the question of material was not as complicated.

¶ Today, however, all these things must be considered even if a building is to be erected in a comparatively small town. Most villages have some kind of water system, electricity and gas are almost everywhere, and the house builder demands more artistry in the design and more comforts within the home. Year by year, the practices of our best builders are becoming more standardized, more refined, and more practical. New methods, new tools, and labor-saving ideas are being evolved as new problems of construction present themselves. It therefore behooves every contractor and builder to keep in touch with the progress of the art by possessing handbooks and reference works which will show him the way.

¶ In the preparation of these volumes, the aim has been to create not merely a work which will appeal to the trained expert but one that will commend itself to the beginner and to the self-taught practical man by broadening his knowledge beyond the limits of his experience.

¶ Another point which has been considered is that, notwithstanding the fact that this is a day of specialists, every contractor and builder must be familiar with the specifications for the foundations, framing, interior work, heating, plumbing, wiring, and other specialties entering into the construction of the building. This information is presented in readable form and will be found adequate for the construction of buildings of moderate size. For the details of construction of large buildings of steel and concrete, readers are referred to our more comprehensive reference work entitled "Architecture, Carpentry, and Building" in ten volumes.

¶ The various sections of this work have been prepared especially for home study by acknowledged experts on the subjects and are as free from technical terms as possible. The importance of such practical subjects as Carpentry, Building Superintendence, Estimating, Steam and Hot-Water Fitting, Drainage and Venting, Blueprint Reading, etc., has been emphasized. The illustrations have been selected with care, and numerous tables and diagrams are introduced wherever possible. It is the hope of the publishers that this reference work will be found of distinct value in its field.

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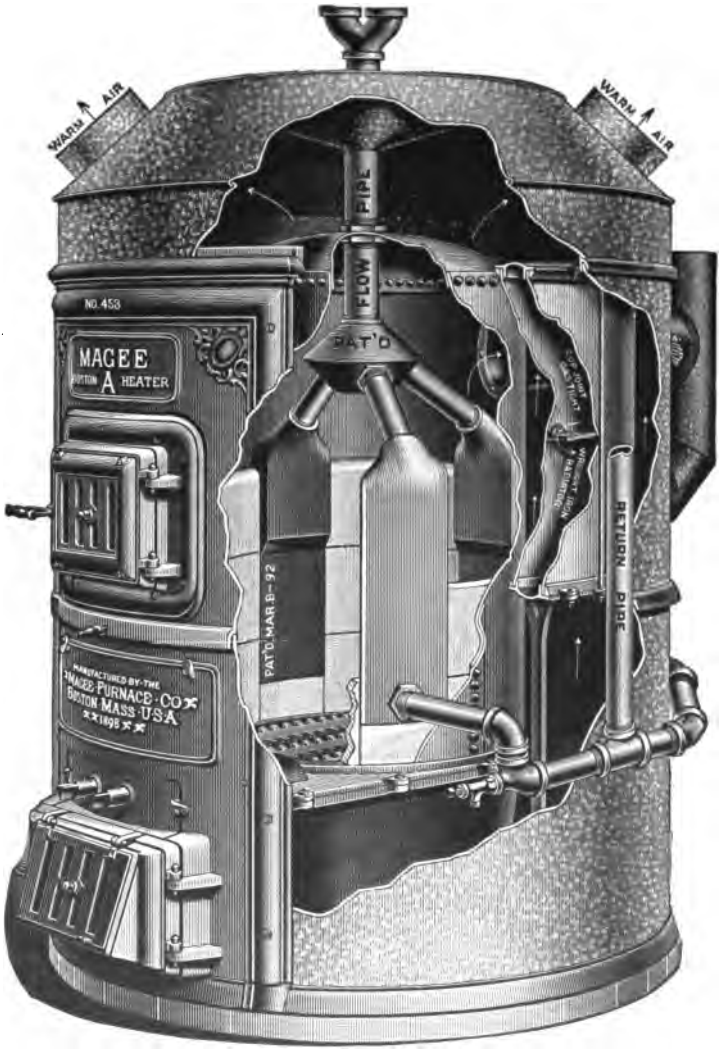


MAGEE TYPE "A" BOSTON HEATER

Courtesy of Magee Furnace Company, Boston, Massachusetts

HEATING AND VENTILATION

PART I

SYSTEMS OF WARMING

Any system of warming must include, *first*, the combustion of fuel, which may take place in a fireplace, stove, or furnace, or a steam, or hot-water boiler; *second*, a system of transmission, by means of which the heat may be carried, with as little loss as possible, to the place where it is to be used for warming; and *third*, a system of diffusion, which will convey the heat to the air in a room, and to its walls, floors, etc., in the most economical way.

Stoves. The simplest and cheapest form of heating is the stove. The heat is diffused by radiation and convection directly to the objects and air in the room, and no special system of transmission is required. The stove is used largely in the country, and is especially adapted to the warming of small dwelling-houses and isolated rooms.

Furnaces. Next in cost of installation and in simplicity of operation, is the hot-air furnace. In this method, the air is drawn over heated surfaces and then transmitted through pipes, while at a high temperature, to the rooms where heat is required. Furnaces are used largely for warming dwelling-houses, also churches, halls, and schoolhouses of small size. They are more costly than stoves, but have certain advantages over that form of heating. They require less care, as several rooms may be warmed from a single furnace; and, being placed in the basement, more space is available in the rooms above, and the dirt and litter connected with the care of a stove are largely done away with. They require less care, as only one fire is necessary to warm all the rooms in a house of ordinary size. One great advantage in the furnace method of warming comes from the constant supply of fresh air which is required to bring the heat into the rooms. While this is greatly to be desired from a sanitary standpoint, it calls for the consumption of a larger amount of fuel than would otherwise be necessary. This is true because heat is required to warm the fresh air from out of doors up to the temperature of the

rooms, in addition to replacing the heat lost by leakage and conduction through walls and windows.

A more even temperature may be maintained with a furnace than by the use of stoves, owing to the greater depth and size of the fire, which allows it to be more easily controlled.

When a building is placed in an exposed location, there is often difficulty in warming rooms on the north and west sides, or on that side toward the prevailing winds. This may be overcome to some extent by a proper location of the furnace and by the use of extra large pipes for conveying the hot air to those rooms requiring special attention.

Direct Steam. Direct steam, so called, is widely used in all classes of buildings, both by itself and in combination with other systems. The first cost of installation is greater than for a furnace; but the amount of fuel required is less, as no outside air supply is necessary. If used for warming hospitals, schoolhouses, or other buildings where a generous supply of fresh air is desired, this method must be supplemented by some form of ventilating system.

One of the principal advantages of direct steam is the ability to heat all rooms alike, regardless of their location or of the action of winds.

When compared with hot-water heating, it has still another desirable feature—which is its freedom from damage by the freezing of water in the radiators when closed, which is likely to happen in unused rooms during very cold weather in the case of the former system.

On the other hand, the sizes of the radiators must be proportioned for warming the rooms in the coldest weather, and unfortunately there is no satisfactory method of regulating the amount of heat in mild weather, except by shutting off or turning on steam in the radiators at more or less frequent intervals as may be required, unless one of the expensive systems of automatic control is employed. In large rooms, a certain amount of regulation can be secured by dividing the radiation into two or more parts, so that different combinations may be used under varying conditions of outside temperature. If two radiators are used, their surface should be proportioned, when convenient, in the ratio of 1 to 2, in which case one-third, two-thirds, or the whole power of the radiation can be used as desired.

Indirect Steam. This system of heating combines some of the advantages of both the furnace and direct steam, but is more costly to install than either of these. The amount of fuel required is about the same as for furnace heating, because in each case the cool fresh air must be warmed up to the temperature of the room, before it can become a medium for conveying heat to offset that lost by leakage and conduction through walls and windows.

A system for indirect steam may be so designed that it will supply a greater quantity of fresh air than the ordinary form of furnace, in which case the cost of fuel will of course be increased in proportion to the volume of air supplied. Instead of placing the radiators in the rooms, a special form of heater is supported near the basement ceiling and encased in either galvanized iron or brick. A cold-air supply duct is connected with the space below the heater, and warm air pipes are taken from the top and connected with registers in the rooms to be heated the same as in the case of furnace heating.

A separate stack or heater may be provided for each register if the rooms are large; but, if small and so located that they may be reached by short runs of horizontal pipe, a single heater may serve for two or more rooms.

The advantage of indirect steam over furnace heating comes from the fact that the stacks may be placed at or near the bases of the flues leading to the different rooms, thus doing away with long, horizontal runs of pipe, and counteracting to a considerable extent the effect of wind pressure upon exposed rooms. Indirect and direct heating are often combined to advantage by using the former for the more important rooms, where ventilation is desired, and the latter for rooms more remote or where heat only is required.

Another advantage is the large ratio between the radiating surface and grate-area, as compared with a furnace; this results in a large volume of air being warmed to a moderate temperature instead of a smaller quantity being heated to a much higher temperature, thus giving a more agreeable quality to the air and rendering it less dry.

Indirect steam is adapted to all the buildings mentioned in connection with furnace heating, and may be used to much better advantage in those of large size. This applies especially to cases where more than one furnace is necessary; for, with steam heat, a single boiler, or a battery of boilers, may be made to supply heat for a build-

ing of any size, or for a group of several buildings, if desired, and is much easier to care for than several furnaces widely scattered.

Direct-Indirect Radiators. These radiators are placed in the room the same as the ordinary direct type. The construction is such that when the sections are in place, small flues are formed between them; and air, being admitted through an opening in the outside wall, passes upward through them and becomes heated before entering the room. A switch damper is placed in the casing at the base of the radiator, so that air may be taken from the room itself instead of from out of doors, if so desired. Radiators of this kind are not used to any great extent, as there is likely to be more or less leakage of cold air into the room around the base. If ventilation is required, it is better to use the regular form of indirect heater with flue and register, if possible. It is sometimes desirable to partially ventilate an isolated room where it would be impossible to run a flue, and in cases of this kind the direct-indirect form is often useful.

Direct Hot Water. Hot water is especially adapted to the warming of dwellings and greenhouses, owing to the ease with which the temperature can be regulated. When steam is used, the radiators are always at practically the same temperature, while with hot water the temperature can be varied at will. A system for hot-water heating costs more to install than one for steam, as the radiators must be larger and the pipes more carefully run. On the other hand, the cost of operating is somewhat less, because the water need be carried only at a temperature sufficiently high to warm the rooms properly in mild weather, while with steam the building is likely to become overheated, and more or less heat wasted through open doors and windows.

A comparison of the relative costs of installing and operating hot-air, steam, and hot-water systems, is given in Table I.

TABLE I

Relative Cost of Heating Systems

	Hot Air	Steam	Hot Water
Relative cost of apparatus	9	13	15
Relative cost, adding repairs and fuel for five years	29½	29¾	27
Relative cost, adding repairs and fuel for fifteen years	81	63	52½

One disadvantage in the use of hot water is the danger from freezing when radiators are shut off in unused rooms. This makes it necessary in very cold weather to have all parts of the system turned on sufficiently to produce a circulation, even if very slow. This is sometimes accomplished by drilling a very small hole (about $\frac{1}{8}$ inch) in the valve-seat, to that when closed there will still be a very slow circulation through the radiator, thus preventing the temperature of the water from reaching the freezing point.

Indirect Hot Water. This is used under the same conditions as indirect steam, but more especially in the case of dwellings and hospitals. When applied to other and larger buildings, it is customary to force the water through the mains by means of a pump. Larger heating stacks and supply pipes are required than for steam; but the arrangement and size of air-flues and registers are practically the same, although they are sometimes made slightly larger in special cases.

Exhaust Steam. Exhaust steam is used for heating in connection with power plants, as in shops and factories, or in office buildings which have their own lighting plants. There are two methods of using exhaust steam for heating purposes. One is to carry a back pressure of 2 to 5 pounds on the engines, depending upon the length and size of the pipe mains; and the other is to use some form of *vacuum system* attached to the returns or air-valves, which tends to reduce the back pressure rather than to increase it.

Where the first method is used and a back pressure carried, either the boiler pressure or the cut-off of the engines must be increased, to keep the mean effective pressure the same and not reduce the horsepower delivered. In general it is more economical to utilize the exhaust steam for heating. There are instances, however, where the relation between the quantities of steam required for heating and for power are such—especially if the engines are run condensing—that it is better to throw the exhaust away and heat with live steam. Where the vacuum method is used, these difficulties are avoided; and for this reason that method is coming into quite common use. If the condensation from the exhaust steam is returned to the boilers, the oil must first be removed; this is usually accomplished by passing the steam through some form of grease extractor as it leaves the engine. The water of condensation is often passed through a separating tank in addition to this, before it is delivered to the return

pumps. It is better, however, to remove a portion of the oil before the steam enters the heating system; otherwise a coating will be formed upon the inner surfaces of the radiators, which will reduce their efficiency to some extent.

Forced Blast. This method of heating, in different forms, is used for the warming of factories, schools, churches, theaters, halls—in fact, any large building where good ventilation is desired. The air for warming is drawn or forced through a heater of special design, and discharged by a fan or blower into ducts which lead to registers placed in the rooms to be warmed. The heater is usually made up in sections, so that steam may be admitted to or shut off from any section independently of the others, and the temperature of the air regulated in this manner. Sometimes a *by-pass damper* is attached, so that part of the air will pass through the heater and part around or over it; in this way the proportions of cold and heated air may be so adjusted as to give the desired temperature to the air entering the rooms. These forms of regulation are common where a blower is used for warming a single room, as in the case of a church or hall; but where several rooms are warmed, as in a schoolhouse. it is customary to use the main or primary heater at the blower for warming the air to a given temperature (somewhat below that which is actually required), and to supplement this by placing secondary coils or heaters at the bottoms of the flues leading to the different rooms. By means of this arrangement, the temperature of each room can be regulated independently of the others. The so-called *double-duct* system is sometimes employed. In this case, two ducts are carried to each register, one supplying hot air and the other cold or tempered air; and a damper for mixing these in the right proportions is placed in the flue, below the register.

Electric Heating. Unless electricity can be produced at a very low cost, it is not practicable for heating residences or large buildings. The electric heater, however, has quite a wide field of application in heating small offices, bathrooms, electric cars, etc. It is a convenient method of warming isolated rooms on cold mornings, in late spring and early fall, when the regular heating apparatus of the building is not in operation. It has the advantage of being instantly available, and the amount of heat can be regulated at will. Electric heaters are clean, do not vitiate the air, and are easily moved from place to place.

PRINCIPLES OF VENTILATION

Closely connected with the subject of heating is the problem of maintaining air of a certain standard of purity in the various buildings occupied.

The introduction of pure air can be done properly only in connection with some system of heating; and no system of heating is complete without a supply of pure air, depending in amount upon the kind of building and the purpose for which it is used.

Composition of the Atmosphere. Atmospheric air is not a simple substance but a mechanical mixture. Oxygen and nitrogen, the principal constituents, are present in very nearly the proportion of one part of oxygen to four parts of nitrogen by weight. Carbonic acid gas, the product of all combustion, exists in the proportion of 3 to 5 parts in 10,000 in the open country. Water in the form of vapor, varies greatly with the temperature and with the exposure of the air to open bodies of water. In addition to the above, there are generally present, in variable but exceedingly small quantities, ammonia, sulphuretted hydrogen, sulphuric, sulphurous, nitric, and nitrous acids, floating organic and inorganic matter, and local impurities. Air also contains ozone, which is a peculiarly active form of oxygen; and lately another constituent called *argon* has been discovered.

Oxygen is the most important element of the air, so far as both heating and ventilation are concerned. It is the active element in the chemical process of combustion and also in the somewhat similar process which takes place in the respiration of human beings. Taken into the lungs, it acts upon the excess of carbon in the blood, and possibly upon other ingredients, forming chemical compounds which are thrown off in the act of respiration or breathing.

Nitrogen. The principal bulk of the atmosphere is nitrogen, which exists uniformly diffused with oxygen and carbonic acid gas. This element is practically inert in all processes of combustion or respiration. It is not affected in composition, either by passing through a furnace during combustion or through the lungs in the process of respiration. Its action is to render the oxygen less active, and to absorb some part of the heat produced by the process of oxidation.

Carbonic acid gas is of itself only a neutral constituent of the atmosphere, like nitrogen; and—contrary to the general impression—its presence in moderately large quantities (if uncombined with other

substances) is neither disagreeable nor especially harmful. Its presence, however, in air provided for respiration, decreases the readiness with which the carbon of the blood unites with the oxygen of the air; and therefore, when present in sufficient quantity, it may cause indirectly, not only serious, but fatal results. The real harm of a vitiated atmosphere, however, is caused by the other constituent gases and by the minute organisms which are produced in the process of respiration. It is known that these other impurities exist in fixed proportion to the amount of carbonic acid present in an atmosphere vitiated by respiration. Therefore, as the relative proportion of carbonic acid can easily be determined by experiment, the fixing of a standard limit of the amount in which it may be allowed, also limits the amounts of other impurities which are found in combination with it.

When carbonic acid is present in excess of 10 parts in 10,000 parts of air, a feeling of weariness and stuffiness, generally accompanied by a headache, will be experienced; while with even 8 parts in 10,000 parts a room would be considered close. For general considerations of ventilation, the limit should be placed at 6 to 7 parts in 10,000, thus allowing an increase of 2 to 3 parts over that present in outdoor air, which may be considered to contain four parts in 10,000 under ordinary conditions.

Analysis of Air. An accurate qualitative and quantitative analysis of air samples can be made only by an experienced chemist. There are, however, several approximate methods for determining the amount of carbonic acid present, which are sufficiently exact for practical purposes. Among these the following is one of the simplest:

The necessary apparatus consists of six clean, dry, and tightly corked bottles, containing respectively 100, 200, 250, 300, 350, and 400 cubic centimeters, a glass tube containing exactly 15 cubic centimeters to a given mark, and a bottle of perfectly clear, fresh limewater. The bottles should be filled with the air to be examined by means of a hand-ball syringe. Add to the smallest bottle 15 cubic centimeters of the limewater, put in the cork, and shake well. If the limewater has a milky appearance, the amount of carbonic acid will be at least 16 parts in 10,000. If the contents of the bottle remain clear, treat the bottle of 200 cubic centimeters in the same manner; a milky appearance or turbidity in this would indicate 12 parts in 10,000. In a similar manner, turbidity in the 250 cubic centimeter bottle indicates

10 parts in 10,000; in the 300, 8 parts; in the 350, 7 parts; and in the 400, less than 6 parts. The ability to conduct more accurate analyses can be attained only by special study and a knowledge of chemical properties and of methods of investigation.

Another method similar to the above, makes use of a glass cylinder containing a given quantity of limewater and provided with a piston. A sample of the air to be tested is drawn into the cylinder by an upward movement of the piston. The cylinder is then thoroughly shaken, and if the limewater shows a milky appearance, it indicates a certain proportion of carbonic acid in the air. If the limewater remains clear, the air is forced out, and another cylinder full drawn in, the operation being repeated until the limewater becomes milky. The size of the cylinder and the quantity of limewater are so proportioned that a change in color at the first, second, third, etc., cylinder full of air indicates different proportions of carbonic acid. This test is really the same in principle as the one previously described; but the apparatus used is in more convenient form.

Air Required for Ventilation. The amount of air required to maintain any given standard of purity can very easily be determined, provided we know the amount of carbonic acid given off in the process of respiration. It has been found by experiment that the average production of carbonic acid by an adult at rest is about .6 cubic foot per hour. If we assume the proportion of this gas as 4 parts in 10,000 in the external air, and are to allow 6 parts in 10,000 in an occupied room, the gain will be 2 parts in 10,000; or, in other words, there will be $\frac{2}{10{,}000} = .0002$ cubic foot of carbonic acid mixed with each cubic foot of fresh air entering the room. Therefore, if one person gives off .6 cubic foot of carbonic acid per hour, it will require $.6 \div .0002 = 3{,}000$ cubic feet of air per hour per person to keep the air in the room at the standard of purity assumed—that is, 6 parts of carbonic acid in 10,000 of air.

Table II has been computed in this manner, and shows the amount of air which must be introduced for each person in order to maintain various standards of purity.

While this table gives the theoretical quantities of air required for different standards of purity, and may be used as a guide, it will be better in actual practice to use quantities which experience has shown

to give good results in different types of buildings. In auditoriums where the cubic space per individual is large, and in which the atmosphere is thoroughly fresh before the rooms are occupied, and the occupancy is of only two or three hours' duration, the air-supply may be reduced somewhat from the figures given below.

TABLE II

Quantity of Air Required per Person

Standard Parts of Carbonic Acid in 10,000 of Air in Room	Cubic Feet of Air Required per Person	
	Per Minute	Per Hour
5	100	6,000
6	50	3,000
7	33	2,000
8	25	1,500
9	20	1,200
10	16	1,000

Table III represents good modern practice and may be used with satisfactory results:

TABLE III

Air Required for Ventilation of Various Classes of Buildings

Air-Supply per Occupant for	Cubic Feet per Minute	Cubic Feet per Hour
Hospitals	80 to 100	4, 800 to 6, 000
High Schools	50	3, 000
Grammar Schools	40	2, 400
Theaters and Assembly Halls	25	1, 500
Churches	20	1, 200

When possible, the air-supply to any given room should be based upon the number of occupants. It sometimes happens, however, that this information is not available, or the character of the room is such that the number of persons occupying it may vary, as in the case of public waiting rooms, toilet rooms, etc. In instances of this kind, the required air-volume may be based upon the number of changes per hour. In using this method, various considerations must be taken into account, such as the use of the room and its condition as to crowding, character of occupants, etc. In general, the following will be found satisfactory for average conditions:

TABLE IV

Number of Changes of Air Required in Various Rooms

Use of Room	Changes of Air per Hour
Public Waiting Room	4 to 5
Public Toilets	5 " 6
Coat and Locker Rooms	4 " 5
Museums	3 " 4
Offices, Public	4 " 5
Offices, Private	3 " 4
Public Dining Rooms	4 " 5
Living Rooms	3 " 4
Libraries, Public	4 " 5
Libraries, Private	3 " 4

Force for Moving Air. Air is moved for ventilating purposes in two ways: (1) by expansion due to heating; (2) by mechanical means. The effect of heat on the air is to increase its volume and therefore lessen its density or weight, so that it tends to rise and is replaced by the colder air below. The available force for moving air obtained in this way is very small, and is quite likely to be overcome by wind or external causes. It will be found in general that the heat used for producing velocity in this manner, when transformed into work in the steam engine, is greatly in excess of that required to produce the same effect by the use of a fan.

Fig. 1. Common Form of Anemometer, for Measuring Velocity of Air-Currents.

Ventilation by mechanical means is performed either by pressure or by suction. The former is used for delivering fresh air into a building, and the latter for removing the foul air from it. By both processes the air is moved without change in temperature, and the force for moving must be sufficient to overcome the effects of wind or changes in outside temperature. Some form of fan is used for this purpose.

Measurements of Velocity. The velocity of air in ventilating ducts and flues is measured directly by an instrument called an anemometer. A common form of this instrument is shown in Fig. 1. It consists of a series of flat vanes attached to an axis, and a series of dials

The revolution of the axis causes motion of the hands in proportion to the velocity of the air, and the result can be read directly from the dials for any given period.

For approximate results the anemometer may be slowly moved across the opening in either vertical or horizontal parallel lines, so that the readings will be made up of velocities taken from all parts of the opening. For more accurate work, the opening should be divided into a number of squares by means of small twine, and readings taken at the center of each. The mean of these readings will give the average velocity of the air through the entire opening.

AIR DISTRIBUTION

The location of the air inlet to a room depends upon the size of the room and the purpose for which it is used. In the case of living rooms in dwelling-houses, the registers are placed either in the floor or in the wall near the floor; this brings the warm air in at the coldest part of the room and gives an opportunity for warming or drying the feet if desired. In the case of schoolrooms, where large volumes of warm air at moderate temperatures are required, it is best to discharge it through openings in the wall at a height of 7 or 8 feet from the floor; this gives a more even distribution, as the warmer air tends to rise and hence spreads uniformly under the ceiling; it then gradually displaces other air, and the room becomes filled with pure air without sensible currents or drafts. The cooler air sinks to the bottom of the room, and can be taken off through ventilating registers placed near the floor. The relative positions of the inlet and outlet are often governed to some extent by the building construction; but, if possible, they should both be located in the same side of the room. Figs. 2, 3, and 4 show common arrangements.

The vent outlet should always, if possible, be placed in an inside wall; otherwise it will become chilled and the air-flow through it will become sluggish. In theaters and churches which are closely packed, the air should enter at or near the floor, in finely-divided streams; and the discharge ventilation should be through openings in the ceiling. The reason for this is the large amount of animal heat given off from the bodies of the audience; this causes the air to become still further heated after entering the room, and the tendency is to rise continuously

from floor to ceiling, thus carrying away all impurities from respiration as fast as they are given off.

All audience halls in which the occupants are closely seated should be treated in the same manner, when possible. This, however, cannot always be done, as the seats are often made removable so that the

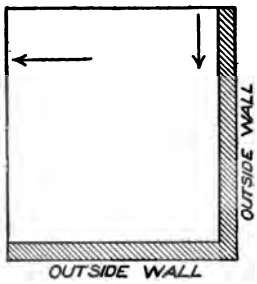


Fig. 2.

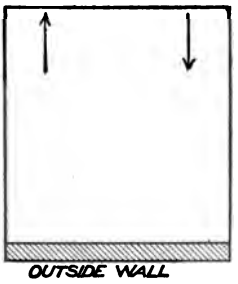


Fig. 3.

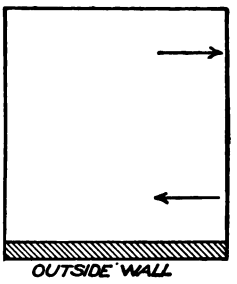


Fig. 4.

Diagrams Showing Relative Positions of Air Inlets and Outlets as Commonly Arranged.

floor can be used for other purposes. In cases of this kind, part of the air may be introduced through floor registers placed along the outer aisles, and the remainder by means of wall inlets the same as for schoolrooms. The discharge ventilation should be partly through registers near the floor, supplemented by ample ceiling vents for use when the hall is crowded or the outside temperature high.

The matter of air-velocities, size of flues, etc., will be taken up under the head of "Indirect Heating."

HEAT LOSS FROM BUILDINGS

A *British Thermal Unit,* or B. T. U., has been defined as the amount of heat required to raise the temperature of one pound of water one degree F. This measure of heat enters into many of the calculations involved in the solving of problems in heating and ventilation, and one should familiarize himself with the exact meaning of the term.

Causes of Heat Loss. The heat loss from a building is due to the following causes: (1) radiation and conduction of heat through walls and windows; (2) leakage of warm air around doors and windows and through the walls themselves; and (3) heat required to warm the air for ventilation.

Loss through Walls and Windows. The loss of heat through the walls of a building depends upon the material used in construction

TABLE V

Heat Losses in B. T. U. per Square Foot of Surface per Hour—Southern Exposure

Material	Difference between Inside and Outside Temperatures									
	10°	20°	30°	40°	50°	60°	70°	80°	90°	100°
8-in. Brick Wall	5	9	13	18	22	27	31	36	40	45
12-in. Brick Wall	4	7	10	13	16	20	23	26	30	33
16-in. Brick Wall	3	5	8	10	13	16	19	22	24	27
20-in. Brick Wall	2.8	4.5	7	9	11	14	16	18	20	23
24-in. Brick Wall	2.5	4	6	8	10	12	14	16	18	20
28-in. Brick Wall	2	3.5	5	7	9	11	13	14	16	18
32-in. Brick Wall	1.5	3	4.5	6	8	10	11	13	15	16
Single Window	12	24	36	49	60	73	85	93	110	122
Double Window	8	16	24	32	40	48	56	62	70	78
Single Skylight	11	21	31	42	52	63	73	84	94	104
Double Skylight	7	14	20	28	35	42	48	56	62	70
1-in. Wooden Door	4	8	12	16	20	24	28	32	36	40
2-in. Wooden Door	3	5	8	11	14	17	20	23	25	28
2-in. Solid Plaster Partition	6	12	18	24	30	36	42	48	54	60
3-in. Solid Plaster Partition	5	10	15	20	25	30	35	40	45	50
Concrete Floor on Brick Arch	2	4	6.5	9	11	13	15	18	20	22
Wood Floor on Brick Arch	1.5	3	4.5	6	7	9	10	12	13	15
Double Wood Floor	1	2	3	4	5	6	7	8	9	10
Walls of Ordinary Wooden Dwellings	3	5	8	10	13	16	19	22	24	27

For *solid stone walls*, multiply the figures for brick of the same thickness by 1.7. Where rooms have a *cold attic above or cellar beneath*, multiply the heat loss through walls and windows by 1.1.

Correction for Leakage. The figures given in the above table apply only to the most thorough construction. For the average well-built house, the results should be increased about 10 per cent; for fairly good construction, 20 per cent; and for poor construction, 30 per cent.

Table V applies only to a southern exposure; for other exposures multiply the heat loss given in Table V by the factors given in Table VI.

of the wall, the thickness, the number of layers, and the difference between the inside and outside temperatures. The exact amount of heat lost in this way is very difficult to determine theoretically, hence we depend principally on the results of experiments.

Loss by Air-Leakage. The leakage of air from a room varies from one to two or more changes of the entire contents per hour, depending upon the construction, opening of doors, etc. It is common practice to allow for one change per hour in well-constructed buildings where two walls of the room have an outside exposure. As the amount of leakage depends upon the extent of exposed wall and window surface, the simplest way of providing for this is to increase

TABLE VI

Factors for Calculating Heat Loss for Other than Southern Exposures

Exposure	Factor
N.	1.32
E.	1.12
S.	1.0
W.	1.20
N. E.	1.22
N. W.	1.26
S. E.	1.06
S. W.	1.10
N., E., S., and W., or total exposure	1.16

the total loss through walls and windows by a factor depending upon the tightness of the building construction. Authorities differ considerably in the factors given for heat losses, and there are various methods for computing the same. The figures given in Table V have been used extensively in actual practice, and have been found to give good results when used with judgment. The table gives the heat losses through different thicknesses of walls, doors, windows, etc., in B. T. U., per square foot of surface per hour, for varying differences in inside and outside temperatures.

In computing the heat loss through walls, only those exposed to the outside air are considered.

In order to make the use of the table clear, we shall give a number of examples illustrating its use:

Example 1. Assuming an inside temperature of 70°, what will be the heat loss from a room having an exposed wall surface of 200 square feet and a glass surface of 50 square feet, when the outside temperature is zero? The wall is of brick, 16 inches in thickness, and has a southern exposure; the windows are single; and the construction is of the best, so that no account need be taken of leakage

We find from Table V, that the factor for a 16-inch brick wall with a difference in temperature of 70° is 19, and that for glass (single window) under the same condition is 85; therefore,

Loss through walls = 200 × 19 = 3,800
Loss through windows = 50 × 85 = 4,250

Total loss per hour = 8,050 B. T. U.

Example 2. A room 15 ft. square and 10 ft. high has two exposed walls, one toward the north, and the other toward the west. There are 4 windows, each 3 feet by 6 feet in size. The two in the north wall are double, while the

other two are single. The walls are of brick, 20 inches in thickness. With an inside temperature of 70°, what will be the heat loss per hour when it is 10° below zero?

Total exposed surface = $15 \times 10 \times 2 = 300$
Glass surface = $3 \times 6 \times 4 = 72$

Net wall surface = 228

Difference between inside and outside temperature 80°.
Factor for 20-inch brick wall is 18.
Factor for single window is 93.
Factor for double window is 62.
The heat losses are as follows:

Wall, $228 \times 18 = 4{,}104$
Single windows, $36 \times 93 = 3{,}348$
Double windows, $36 \times 62 = 2{,}232$

9,684 B. T. U.

As one side is toward the north, and the other toward the west, the actual exposure is N. W. Looking in Table VI, we find the correction factor for this exposure to be 1.26; therefore the total heat loss is

$$9{,}684 \times 1.26 = 12{,}201.84 \text{ B. T. U.}$$

Example 3. A dwelling-house of fair wooden construction measures 160 ft. around the outside; it has 2 stories, each 8 ft. in height; the windows are single, and the glass surface amounts to one-fifth the total exposure; the attic and cellar are unwarmed. If 8,000 B. T. U. are utilized from each pound of coal burned in the furnace, how many pounds will be required per hour to maintain a temperature of 70° when it is 20° above zero outside?

Total exposure = $160 \times 16 = 2{,}560$
Glass surface = $2{,}560 \div 5 = 512$

Net wall = 2,048

Temperature difference = $70 - 20 = 50°$
Wall $2{,}048 \times 13 = 26{,}624$
Glass $512 \times 60 = 30{,}720$

57,344 B. T. U.

As the building is exposed on all sides, the factor for exposure will be the average of those for N., E., S., and W., or

$$(1.32 + 1.12 + 1.0 + 1.20) \div 4 = 1.16$$

The house has a cold cellar and attic, so we must increase the heat loss

10 per cent for each of the first two conditions, and 20 per cent for the last. Making these corrections we have:

$$57{,}344 \times 1.16 \times 1.10 \times 1.10 \times 1.20 = 96{,}338 \text{ B. T. U.}$$

If one pound of coal furnishes 8,000 B. T. U., then $96{,}338 \div 8{,}000 =$ 12 pounds of coal per hour required to warm the building to 70° under the conditions stated.

Approximate Method. For dwelling-houses of the average construction, the following simple method for calculating the heat loss may be used. Multiply the total exposed surface by 45, which will give the heat loss in B. T. U. per hour for an inside temperature of 70° in zero weather.

This factor is obtained in the following manner: Assume the glass surface to be one-sixth the total exposure, which is an average proportion. Then each square foot of exposed surface consists one-sixth of glass and five-sixths of wall, and the heat loss for 70° difference in temperature would be as follows:

$$\text{Wall } \frac{5}{6} \times 19 = 15.8$$

$$\text{Glass } \frac{1}{6} \times 85 = \underline{14.1}$$

$$29.9$$

Increasing this 20 per cent for leakage, 16 per cent for exposure, and 10 per cent for cold ceilings, we have:

$$29.9 \times 1.20 \times 1.16 \times 1.10 = 45.$$

The loss through floors is considered as being offset by including the kitchen walls of a dwelling-house, which are warmed by the range, and which would not otherwise be included if computing the size of a furnace or boiler for heating.

If the heat loss is required for outside temperatures other than zero, multiply by 50 for 10 degrees below, and by 40 for 10 degrees above zero.

This method is convenient for approximations in the case of dwelling-houses; but the more exact method should be used for other types of buildings, and in all cases for computing the heating surface for separate rooms. *When calculating the heat loss from isolated rooms, the cold inside walls as well as the outside must be considered.*

The loss through a wall next to a cold attic or other unwarmed space may in general be taken as about two-thirds that of an outside wall.

Heat Loss by Ventilation. One B. T. U. will raise the temperature of 1 cubic foot of air 55 degrees at average temperatures and pressures, or will raise 55 cubic feet 1 degree, so that the heat required for the ventilation of any room can be found by the following formula:

$$\frac{\text{Cu. ft. of air per hour} \times \text{Number of degrees rise}}{55} = \text{B. T. U. required.}$$

To compute the heat loss for any given room which is to be ventilated, first find the loss through walls and windows, and correct for exposure and leakage; then compute the amount required for ventilation as above, and take the sum of the two. An inside temperature of 70° is always assumed unless otherwise stated.

Examples. What quantity of heat will be required to warm 100,000 cubic feet of air to 70° for ventilating purposes when the outside temperature is 10 below zero?

$$100{,}000 \times 80 \div 55 = 145{,}454 \text{ B. T. U.}$$

How many B. T. U. will be required per hour for the ventilation of a church seating 500 people, in zero weather?

Referring to Table III, we find that the total air required per hour is $1{,}200 \times 500 = 600{,}000$ cu. ft.; therefore $600{,}000 \times 70 \div 55 = 763{,}636$ B. T. U.

The factor $\frac{\text{Rise in Temperature}}{55}$ is approximately 1.1 for 60°, 1.3 for 70°, and 1.5 for 80°. Assuming a temperature of 70° for the entering air, we may multiply the air-volume supplied for ventilation by 1.1 for an outside temperature of 10° above 0, by 1.3 for zero, and by 1.5 for 10° below zero—which covers the conditions most commonly met with in practice.

EXAMPLES FOR PRACTICE

1. A room in a grammar school 28 ft. by 32 ft. and 12 feet high is to accommodate 50 pupils. The walls are of brick 16 inches in thickness; and there are 6 single windows in the room, each 3 ft. by 6 ft.; there are warm rooms above and below; the exposure is S. E. How many B. T. U. will be required per hour for warming the room, and how many for ventilation, in zero weather, assuming the building to be of average construction?

ANS. 22,056 + for warming; 152,727 + for ventilation.

2. A stone church seating 400 people has walls 20 inches in thickness. It has a wall exposure of 5,000 square feet, a glass expos-

are (single windows) of 600 square feet, and a roof exposure of 7,000 square feet; the roof is of 2-inch pine plank, and the factor for heat loss may be taken the same as for a 2-inch wooden door. The floor is of wood on brick arches, and has an area of 4,000 square feet. The building is exposed on all sides, and is of first-class construction. What will be the heat required per hour for both warming and ventilation when the outside temperature is 20° above zero?

ANS. 296,380 for warming; 436,363 + for ventilation.

3. A dwelling-house of average wooden construction measures 200 feet around the outside, and has 3 stories, each 9 feet high. Compute the heat loss by the approximate method when the temperature is 10° below zero.

ANS. 270,000 B. T. U. per hour.

FURNACE HEATING

In construction, a furnace is a large stove with a combustion chamber of ample size over the fire, the whole being inclosed in a casing of sheet iron or brick. The bottom of the casing is provided with a cold-air inlet, and at the top are pipes which connect with registers placed in the various rooms to be heated. Cold, fresh air is brought from out of doors through a pipe or duct called the *cold-air box;* this air enters the space between the casing and the furnace near the bottom, and, in passing over the hot surfaces of the fire-pot and combustion chamber, becomes heated. It then rises through the warm-air pipes at the top of the casing, and is discharged through the registers into the rooms above.

As the warm air is taken from the top of the furnace, cold air flows in through the cold-air box to take its place. The air for heating the rooms does not enter the combustion chamber.

Fig. 5 shows the general arrangement of a furnace with its connecting pipes. The cold-air inlet is seen at the bottom, and the hot-air pipes at the top; these are all provided with dampers for shutting off or regulating the amount of air flowing through them. The feed or fire door is shown at the front, and the ash door beneath it; a *water-pan* is placed inside the casing, and furnishes moisture to the warm air before passing into the rooms; water is either poured into the pan through an opening in the front, provided for this purpose, or is supplied automatically through a pipe.

The fire is regulated by means of a draft slide in the ash door, and a cold-air or regulating damper placed in the smoke-pipe. Clean-out doors are placed at different points in the casing for the removal of

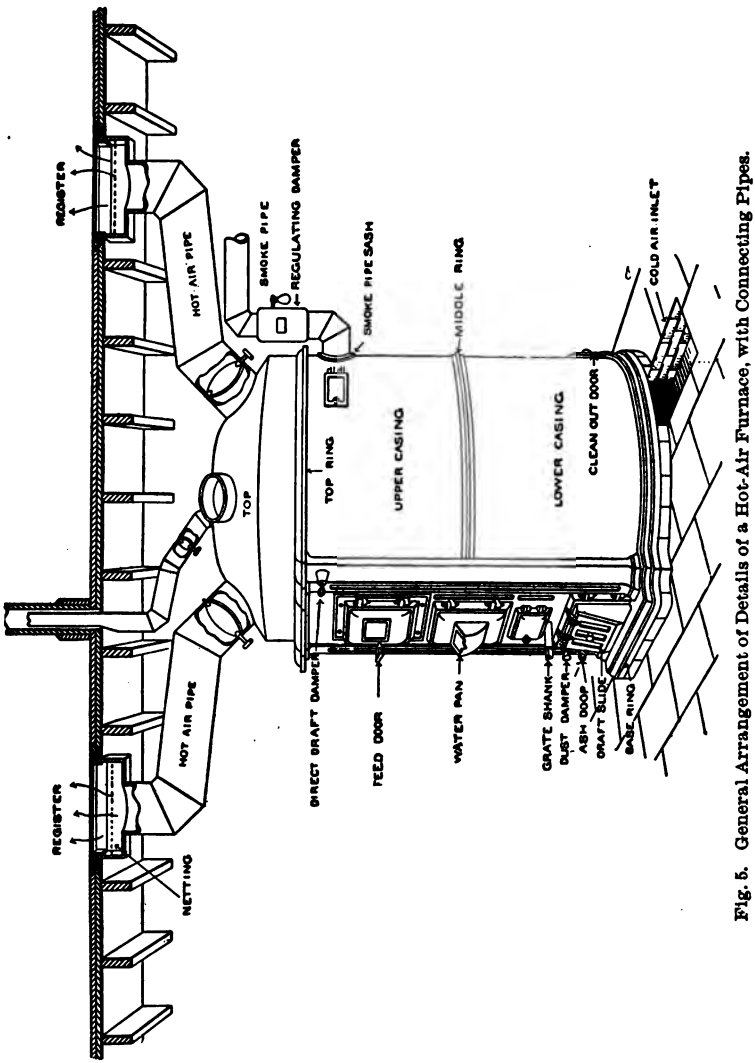


Fig. 5. General Arrangement of Details of a Hot-Air Furnace, with Connecting Pipes.

ashes and soot. Furnaces are made either of cast iron, or of wrought-iron plates riveted together and provided with brick-lined firepots.

Types of Furnaces. Furnaces may be divided into two general

types known as *direct-draft* and *indirect-draft*. Fig. 6 shows in section a common form of *direct-draft* furnace; the better class have a radiator, generally placed at the top, through which the gases pass before reaching the smoke-pipe. They have but one damper, usually combined with a cold-air check. Many of the cheaper direct-draft

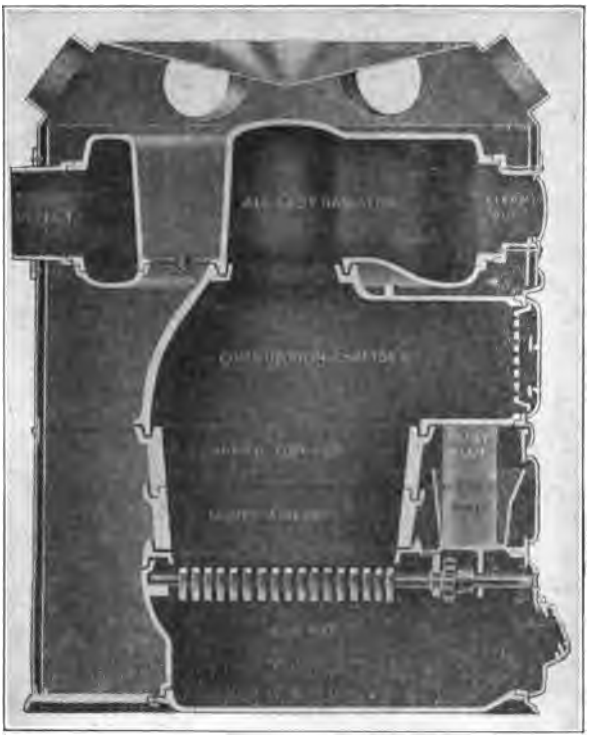


Fig. 6. Section through Direct-Draft Furnace.
Courtesy of Fuller-Warren Company, Milwaukee, Wisconsin.

furnaces have no radiator at all, the gases passing directly into the smoke-pipe and carrying away much heat that should be utilized.

The furnace shown in Fig. 6 is made of cast iron and has a large radiator at the top; the smoke connection is shown at the rear.

Fig. 7 represents another form of direct-draft furnace. In this case the radiator is made of sheet-steel plates riveted together with tubular flues passing through it.

In the ordinary *indirect-draft* type of furnace (see Fig. 8), the gases pass downward through flues to a radiator located near the base,

thence upward through another flue to the smoke-pipe. In addition to the damper in the smoke-pipe, a direct-draft damper is required to give direct connection with the funnel when coal is first put on, to facilitate the escape of gas to the chimney. When the chimney draft

Fig. 7. Stewart "B" Direct-Draft Furnace with Tubular Steel Radiator. Portable Form for Hard or Soft Coal.
Courtesy of Fuller-Warren Company, Milwaukee, Wisconsin.

is weak, trouble from gas is more likely to be experienced with furnaces of this type than with those having a direct draft.

Grates. No part of a furnace is of more importance than the grates. The plain grate rotating about a center pin was for a long time the one most commonly used. These grates were usually provided with a clinker door for removing any refuse too large to pass between the grate bars. The action of such grates tends to leave a

cone of ashes in the center of the fire causing it to burn more freely around the edges. A better form of grate is the revolving triangular pattern, which is now used in many of the leading furnaces. It consists of a series of triangular bars having teeth. The bars are connected by gears, and are turned by means of a detachable lever. If

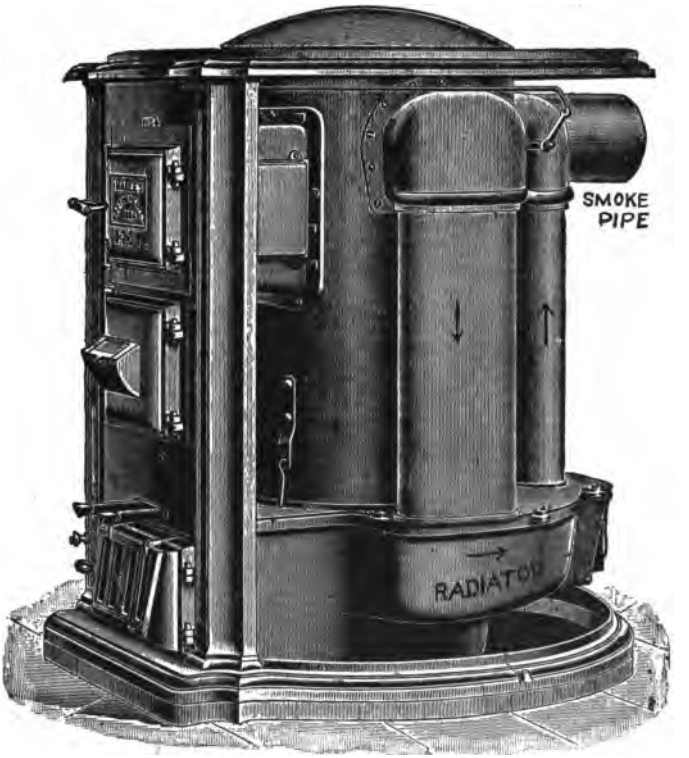


Fig. 8. Indirect-Draft Type of Furnace. Gases Pass Downward to Radiator at Bottom, Thence Upward to Smoke-Pipe.

properly used, this grate will cut a slice of ashes and clinkers from under the entire fire with little, if any loss of unconsumed coal.

The Firepot. Firepots are generally made of cast iron or of steel plate lined with firebrick. The depth ranges from about 12 to 18 inches. In cast-iron furnaces of the better class, the firepot is made very heavy, to insure durability and to render it less likely to become red-hot. The firepot is sometimes made in two pieces, to reduce the

liability to cracking. The heating surface is sometimes increased by corrugations, pins, or ribs.

A firebrick lining is necessary in a wrought-iron or steel furnace to protect the thin shell from the intense heat of the fire. Since brick-lined firepots are much less effective than cast-iron in transmitting heat, such furnaces depend to a great extent for their efficiency on the heating surface in the dome and radiator; and this, as a rule, is much greater than in those of cast iron.

Cast-iron furnaces have the advantage when coal is first put on (and the drop flues and radiator are cut out by the direct damper) of still giving off heat from the firepot, while in the case of brick linings very little heat is given off in this way, and the rooms are likely to become somewhat cooled before the fresh coal becomes thoroughly ignited.

Combustion Chamber. The body of the furnace above the fire-pot, commonly called the *dome* or *feed section*, provides a combustion chamber. This chamber should be of sufficient size to permit the gases to become thoroughly mixed with the air passing up through the fire or entering through openings provided for the purpose in the feed door. In a well-designed furnace, this space should be somewhat larger than the firepot.

Radiator. The radiator, so called, with which all furnaces of the better class are provided, acts as a sort of reservoir in which the gases are kept in contact with the air passing over the furnace until they have parted with a considerable portion of their heat. Radiators are built of cast iron, of steel plate, or of a combination of the two. The former is more durable and can be made with fewer joints, but owing to the difficulty of casting radiators of large size, steel plate is commonly used for the sides.

The effectiveness of a radiator depends on its form, its heating surface, and the difference between the temperature of the gases and the surrounding air. Owing to the accumulation of soot, the bottom surface becomes practically worthless after the furnace has been in use a short time; surfaces, to be effective, must therefore be self-cleaning.

If the radiator is placed near the bottom of the furnace the gases are surrounded by air at the lowest temperature, which renders the radiator more effective for a given size than if placed near the top and

surrounded by warm air. On the other hand, the cold air has a tendency to condense the gases, and the acids thus formed are likely to corrode the iron.

Heating Surface. The different heating surfaces may be described as follows: Firepot surface; surfaces acted upon by direct rays of heat from the fire, such as the dome or combustion chamber; gas- or smoke-heated surfaces, such as flues or radiators; and extended surfaces, such as pins or ribs. Surfaces unlike in character and location, vary greatly in heating power, so that, in making comparisons of different furnaces, we must know the kind, form, and location of the heating surfaces, as well as the area.

In some furnaces having an unusually large amount of surface, it will be found on inspection that a large part would soon become practically useless from the accumulation of soot. In others a large portion of the surface is lined with firebrick, or is so situated that the air-currents are not likely to strike it.

The ratio of grate to heating surface varies somewhat according to the size of furnace. It may be taken as 1 to 25 in the smaller sizes, and 1 to 15 in the larger.

Efficiency. One of the first items to be determined in estimating the heating capacity of a furnace, is its efficiency—that is, the proportion of the heat in the coal that may be utilized for warming. The efficiency depends chiefly on the area of the heating surface as compared with the grate, on its character and arrangement, and on the rate of combustion. The usual proportions between grate and heating surface have been stated. The rate of combustion required to maintain a temperature of 70° in the house, depends, of course, on the outside temperature. In very cold weather a rate of 4 to 5 pounds of coal per square foot of grate per hour must be maintained.

One pound of good anthracite coal will give off about 13,000 B. T. U., and a good furnace should utilize 70 per cent of this heat. The efficiency of an ordinary furnace is often much less, sometimes as low as 50 per cent.

In estimating the required size of a first-class furnace with good chimney draft, we may safely count upon a maximum combustion of 5 pounds of coal per square foot of grate per hour, and may assume that 8,000 B. T. U. will be utilized for warming purposes from each

pound burned. This quantity corresponds to an efficiency of 60 per cent.

Heating Capacity. Having determined the heat loss from a building by the methods previously given, it is a simple matter to compute the size of grate necessary to burn a sufficient quantity of coal to furnish the amount of heat required for warming.

In computing the size of furnace, it is customary to consider the whole house as a single room, with four outside walls and a cold attic. The heat losses by conduction and leakage are computed, and increased 10 per cent for the cold attic, and 16 per cent for exposure. The heat delivered to the various rooms may be considered as being made up of two parts—*first*, that required to warm the outside air up to 70° (the temperature of the rooms); and *second*, the quantity which must be added to this to offset the loss by conduction and leakage. Air is usually delivered through the registers at a temperature of 120°, with zero conditions outside, in the best class of residence work; so that $\frac{70}{120}$ of the heat given to the entering air may be considered as making up the first part, mentioned above, leaving $\frac{50}{120}$ available for purely heating purposes. From this it is evident that the heat supplied to the entering air must be equal to $1 \div \frac{50}{120} = 2.4$ times that required to offset the loss by conduction and leakage.

Example. The loss through the walls and windows of a building is found to be 80,000 B. T. U. per hour in zero weather. What will be the size of furnace required to maintain an inside temperature of 70 degrees?

From the above, we have the total heat required, equal to $80{,}000 \times 2.4 = 192{,}000$ B. T. U. per hour. If we assume that 8,000 B. T. U. are utilized per pound of coal, then $192{,}000 \div 8{,}000 = 24$ pounds of coal required per hour; and if 5 pounds can be burned on each square foot of grate per hour, then $\frac{24}{5} = 4.8$ square feet required. A grate 30 inches in diameter has an area of 4.9 square feet, and is the size we should use.

When the outside temperature is taken as 10° below zero, multiply by 2.6 instead of 2.4; and multiply by 2.8 for 20° below.

Table VII will be found useful in determining the diameter of firepot required.

TABLE VII

Firepot Dimensions

Average Diameter of Grate, in Inches	Area in Square Feet
18	1.77
20	2.18
22	2.64
24	3.14
26	3.69
28	4.27
30	4.91
32	5.58

EXAMPLES FOR PRACTICE

1. A brick apartment house is 20 feet wide, and has 4 stories, each being 10 feet in height. The house is one of a block, and is exposed only at the front and rear. The walls are 16 inches thick, and the block is so sheltered that no correction need be made for exposure. Single windows make up $\frac{1}{8}$ the total exposed surface. Figure for cold attic but warm basement. What area of grate surface will be required for a furnace to keep the house at a temperature of 70° when it is 10° below zero outside? Ans. 3.5 square feet.

2. A house having a furnace with a firepot 30 inches in diameter, is not sufficiently warmed, and it is decided to add a second furnace to be used in connection with the one already in. The heat loss from the building is found by computation to be 133,600 B. T. U. per hour, in zero weather. What diameter of firepot will be required for the extra furnace? Ans. 24 inches.

Location of Furnace. A furnace should be so placed that the warm-air pipes will be of nearly the same length. The air travels most readily through pipes leading toward the sheltered side of the house and to the upper rooms. Therefore pipes leading toward the north or west, or to rooms on the first floor, should be favored in regard to length and size. The furnace should be placed somewhat to the north or west of the center of the house, or toward the points of compass from which the prevailing winds blow.

Smoke-Pipes. Furnace smoke-pipes range in size from about 6 inches in the smaller sizes to 8 or 9 inches in the larger ones. They are generally made of galvanized iron of No. 24 gauge or heavier. The pipe should be carried to the chimney as directly as possible,

avoiding bends which increase the resistance and diminish the draft. Where a smoke-pipe passes through a partition, it should be protected by a soapstone or double-perforated metal collar having a diameter at least 8 inches greater than that of the pipe. The top of the smoke-pipe should not be placed within 8 inches of unprotected beams, nor less than 6 inches under beams protected by asbestos or plaster with a metal shield beneath. A collar to make tight connection with the chimney should be riveted to the pipe about 5 inches from the end, to prevent the pipe being pushed too far into the flue. Where the pipe is of unusual length, it is well to cover it to prevent loss of heat and the condensation of smoke.

Chimney Flues. Chimney flues, if built of brick, should have walls 8 inches in thickness, unless terra-cotta linings are used, when only 4 inches of brickwork is required. Except in small houses where an 8 by 8-inch flue may be used, the nominal size of the smoke flue should be at least 8 by 12-inches, to allow for contractions or offsets. A clean-out door should be placed at the bottom of the flue, for removing ashes and soot. A square flue cannot be reckoned at its full area, as the corners are of little value. To avoid down drafts, the top of the chimney must be carried above the highest point of the roof unless provided with a suitable hood or top.

Cold-Air Box. The cold-air box should be large enough to supply a volume of air sufficient to fill all the hot-air pipes at the same time. If the supply is too small, the distribution is sure to be unequal, and the cellar will become overheated from lack of air to carry away the heat generated.

If a box is made too small, or is throttled down so that the volume of air entering the furnace is not large enough to fill all the pipes, it will be found that those leading to the less exposed side of the house or to the upper rooms will take the entire supply, and that additional air to supply the deficiency will be drawn down through registers in rooms less favorably situated. It is common practice to make the area of the cold-air box three-fourths the combined area of the hot-air pipes. The inlet should be placed where the prevailing cold winds will blow into it; this is commonly on the north or west side of the house. If it is placed on the side away from the wind, warm air from the furnace is likely to be drawn out through the cold-air box.

Whatever may be the location of the entrance to the cold-air box, changes in the direction of the wind may take place which will bring the inlet on the wrong side of the house. To prevent the possibility of such changes affecting the action of the furnace, the cold-air box is sometimes extended through the house and left open at both ends, with check-dampers arranged to prevent back-drafts. These checks should be placed some distance from the entrance, to prevent their becoming clogged with snow or sleet.

The cold-air box is generally made of matched boards; but galvanized iron is much better; it costs more than wood, but is well worth the extra expense on account of tightness, which keeps the dust and ashes from being drawn into the furnace casing to be discharged through the registers into the rooms above.

The cold-air inlet should be covered with galvanized wire netting with a mesh of at least three-eighths of an inch. The frame to which it is attached should not be smaller than the inside dimensions of the cold-air box. A door to admit air from the cellar to the cold-air box is generally provided. As a rule, air should be taken from this source, only when the house is temporarily unoccupied or during high winds.

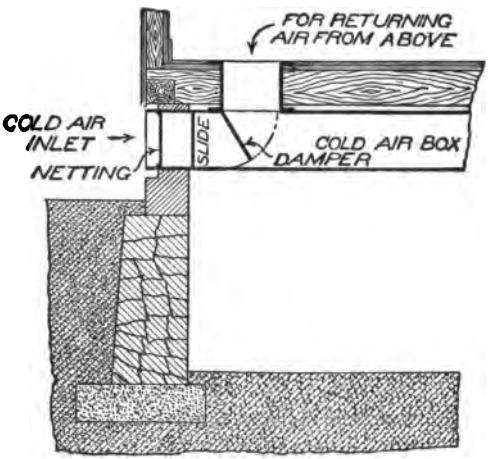


Fig 9. Common Method of Connecting Return Duct to Cold-Air Box.

Return Duct. In some cases it is desirable to return air to the furnace from the rooms above, to be reheated. Ducts for this purpose are common in places where the winter temperature is frequently below zero. Return ducts when used, should be in addition to the regular cold-air box. Fig. 9 shows a common method of making the connection between the two. By proper adjustment of the swinging damper, the air can be taken either from out of doors or through the register from the room above. The return register is often placed in the hallway of

a house, so that it will take the cold air which rushes in when the door is opened and also that which may leak in around it while closed. Check-valves or flaps of light gossamer or woolen cloth should be placed between the cold-air box and the registers to prevent back-drafts during winds.

The return duct should not be used too freely at the expense of outdoor air, and its use is not recommended except during the night when air is admitted to the sleeping rooms through open windows.

Warm-Air Pipes. The required size of the warm-air pipe to any given room, depends on the heat loss from the room and on the volume of warm air required to offset this loss. Each cubic foot of air warmed from zero to 120 degrees brings into a room 2.2 B. T. U. We have already seen that in zero weather, with the air entering the registers at 120 degrees, only $\frac{50}{120}$ of the heat contained in the air is available for offsetting the losses by radiation and conduction, so that only $2.2 \times \frac{50}{120} = .9$ B. T. U. in each cubic foot of entering air can be utilized for warming purposes. Therefore, if we divide the computed heat loss in B. T. U. from a room, by .9, it will give the number of cubic feet of air at 120 degrees necessary to warm the room in zero weather.

As the outside temperature becomes colder, the quantity of heat brought in per cubic foot of air increases; but the proportion available for warming purposes becomes less at nearly the same rate, so

TABLE VIII

Warm-Air Pipe Dimensions

Diameter of Pipe, in Inches	Area in Square Inches	Area in Square Feet
6	28	.196
7	38	.267
8	50	.349
9	64	.442
10	79	.545
11	95	.660
12	113	.785
13	133	.922
14	154	1.07
15	177	1.23
16	201	1.40

that for all practical purposes we may use the figure .9 for all usual conditions. In calculating the size of pipe required, we may assume maximum velocities of 260 and 380 feet per minute for rooms on the first and second floors respectively. Knowing the number of cubic feet of air per minute to be delivered, we can divide it by the velocity, which will give us the required area of the pipe in square feet.

Round pipes of tin or galvanized iron are used for this purpose. Table VIII will be found useful in determining the required diameters of pipe in inches.

Example. The heat loss from a room on the second floor is 18,000 B. T. U. per hour. What diameter of warm-air pipe will be required?

18,000 ÷ .9 = 20,000 = cubic feet of air required per hour. 20,000 ÷ 60 = 333 per minute. Assuming a velocity of 380 feet per minute, we have 333 ÷ 380 = .87 square foot, which is the area of pipe required. Referring to Table VIII, we find this comes between a 12-inch and a 13-inch pipe, and the larger size would probably be chosen.

EXAMPLES FOR PRACTICE

1. A first-floor room has a computed loss of 27,000 B. T. U. per hour when it is 10° below zero. The air for warming is to enter through two pipes of equal size, and at a temperature of 120 degrees. What will be the required diameter of the pipes?

ANS. 14 inches.

2. If in the above example the room had been on the second floor, and the air was to be delivered through a single pipe, what diameter would be required?

ANS. 16 inches.

Since long horizontal runs of pipe increase the resistance and loss of heat, they should not in general be over 12 or 14 feet in length. This applies especially to pipes leading to rooms on the first floor, or to those on the cold side of the house. Pipes of excessive length should be increased in size because of the added resistance.

Figs. 10 and 11 show common methods of running the pipes in the basement. The first gives the best results, and should be used where the basement is of sufficient height to allow it. A damper should be placed in each pipe near the furnace, for regulating the flow of air to the different rooms, or for shutting it off entirely when desired.

While round pipe risers give the best results, it is not always possible to provide a sufficient space for them, and flat or oval pipes are substituted. When vertical pipes must be placed in single partitions, much better results will be obtained if the studding can be

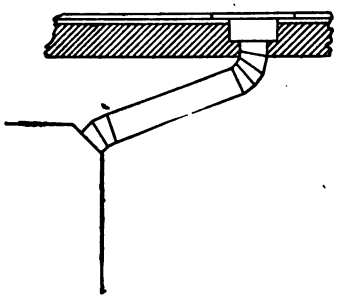


Fig. 10.

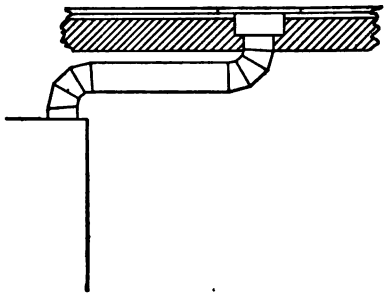


Fig. 11.

Common Methods of Running Hot-Air Pipes in Basement. Method Shown in Fig. 10 is Preferable where Feasible.

made 5 or 6 inches deep instead of 4 as is usually done. Flues should never in any case be made less than 3½ inches in depth. Each room should be heated by a separate pipe. In some cases, however, it is allowable to run a single riser to heat two unimportant rooms on an upper floor. A clear space of at least ½ inch should be left between the risers and studs, and the latter should be carefully tinned, and the

TABLE IX

Dimensions of Oval Pipes

Dimension of Pipe	Area in Square Inches
6 ovaled to 5 in.	27
7 " " 4 "	31
7 " " 3½ "	29
7 " " 6 "	38
8 " " 5 "	43
9 " " 4 "	45
9 " " 6 "	57
9 " " 5 "	51
10 " " 3½ "	46
11 " " 4 "	58
12 " " 3½ "	55
10 " " 6 "	67
11 " " 5 "	67
14 " " 4 "	76
15 " " 3½ "	78
12 " " 6 "	85
12 " " 5 "	75
19 " " 4 "	96
20 " " 3½ "	100

space between them on both sides covered with tin, asbestos, or wire lath.

Table IX gives the capacity of oval pipes. A 6-inch pipe ovaled to 5 means that a 6-inch pipe has been flattened out to a thickness of 5 inches, and column 2 gives the resulting area.

Having determined the size of round pipe required, an equivalent oval pipe can be selected from the table to suit the space available.

Registers. The registers which control the supply of warm air to the rooms, generally have a net area equal to two-thirds of their gross area. The net area should be from 10 to 20 per cent greater than the area of the pipe connected with it. It is common practice to use registers having the short dimensions equal to, and the long dimensions about one-half greater than, the diameter of the pipe. This would give standard sizes for different diameters of pipe, as listed in Table X.

TABLE X

Sizes of Registers for Different Sizes of Pipes

Diameter of Pipe	Size of Register
6 in.	6 × 10 in.
7 "	7 × 10 "
8 "	8 × 12 "
9 "	9 × 14 "
10 "	10 × 15 "
11 "	11 × 16 "
12 "	12 × 17 "
13 "	14 × 20 "
14 "	14 × 22 "
15 "	15 × 22 "
16 "	16 × 24 "

Combination Systems. A combination system for heating by hot air and hot water consists of an ordinary furnace with some form of surface for heating water, placed either in contact with the fire or suspended above it. Fig. 12 shows a common arrangement where part of the heating surface forms a portion of the lining to the firepot and the remainder is above the fire.

Care must be taken to proportion properly the work to be done by the air and the water; else one will operate at the expense of the other. One square foot of heating surface in contact with the fire is capable of supplying from 40 to 50 square feet of radiating surface,

and one square foot suspended over the fire will supply from 15 to 25 square feet of radiation.

The value or efficiency of the heating surface varies so widely in different makes that it is best to state the required conditions to the

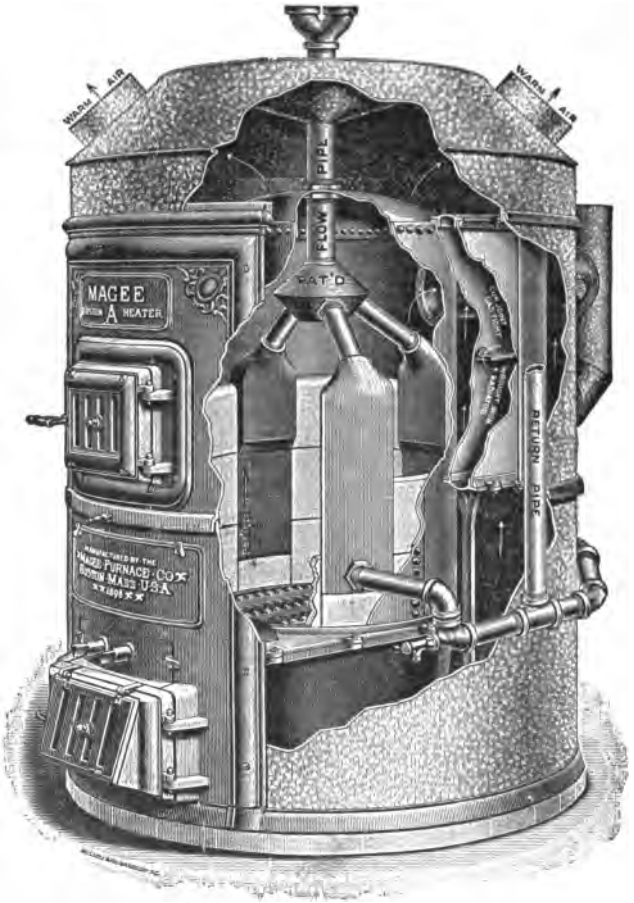


Fig. 12. Combination Furnace, for Heating by Both Hot Air and Hot Water.

manufacturers and have them proportion the surfaces as their experience has found best for their particular type of furnace.

Care and Management of Furnaces. The following general rules apply to the management of all hard coal furnaces.

The fire should be thoroughly shaken once or twice daily in cold weather. It is well to keep the firepot heaping full at all times. In

this way a more even temperature may be maintained, less attention is required, and no more coal is burned than when the pot is only partly filled. In mild weather the mistake is frequently made of carrying a thin fire, which requires frequent attention and is likely to die out. Instead, to diminish the temperature in the house, keep the firepot full and allow ashes to accumulate on the grate (not under it) by shaking less frequently or less vigorously. The ashes will hold the heat and render it an easy matter to maintain and control the fire. When feeding coal on a low fire, open the drafts and neither rake nor shake the fire till the fresh coal becomes ignited. The air supply to the fire is of the greatest importance. An insufficient amount results in incomplete combustion and a great loss of heat. To secure proper combustion, the fire should be controlled principally by means of the ash-pit through the ash-pit door or slide.

The smoke-pipe damper should be opened only enough to carry off the gas or smoke and to give the necessary draft. The openings in the feed door act as a check on the fire, and should be kept closed during cold weather, except just after firing, when with a good draft they may be partly opened to increase the air-supply and promote the proper combustion of the gases.

Keep the ash-pit clear to avoid warping or melting the grate. The cold-air box should be kept wide open except during winds or when the fire is low. At such times it may be partly, but never completely closed. Too much stress cannot be laid on the importance of a sufficient air-supply to the furnace. It costs little if any more to maintain a comfortable temperature in the house night and day than to allow the rooms to become so cold during the night that the fire must be forced in the morning to warm them up to a comfortable temperature.

In case the warm air fails at times to reach certain rooms, it may be forced into them by temporarily closing the registers in other rooms. The current once established will generally continue after the other registers have been opened.

It is best to burn as hard coal as the draft will warrant. Egg size is better than larger coal, since for a given weight small lumps expose more surface and ignite more quickly than larger ones. The furnace and smoke-pipe should be thoroughly cleaned once a year.

This should be done just after the fire has been allowed to go out in the spring.

STEAM BOILERS

Types. The boilers used for heating are the same as have already been described for power work. In addition there is the cast-iron sectional boiler, used almost exclusively for dwelling-houses.

Tubular Boilers. Tubular boilers are largely used for heating purposes, and are adapted to all classes of buildings except dwelling-houses and the special cases mentioned later, for which sectional boilers are preferable. A *boiler horse-power* has been defined as the evaporation of 34½ pounds of water from and at a temperature of 212 degrees, and in doing this 33,317 B. T. U. are absorbed, which are again given out when the steam is condensed in the radiators. Hence to find the boiler H. P. required for warming any given building, we have only to compute the heat loss per hour by the methods already given, and divide the result by 33,330. It is more common to divide by the number 33,000, which gives a slightly larger boiler and is on the side of safety.

The commercial horse-power of a well-designed boiler is based upon its heating surface; and for the best economy in heating work, it should be so proportioned as to have about 1 square foot heating of surface for each 2 pounds of water to be evaporated from and at 212 degrees F. This gives $34.5 \div 2 = 17.2$ square feet of heating surface per horse-power, which is generally taken as 15 in practice. Makers of tubular boilers commonly rate them on a basis of 12 square feet of heating surface per horse-power. This is a safe figure under the conditions of power work, where skilled firemen are employed and where more care is taken to keep the heating surfaces free from soot and ashes. For heating plants, however, it is better to rate the boilers upon 15 square feet per horse-power as stated above.

There is some difference of opinion as to the proper method of computing the heating surface of tubular boilers. In general, all surface is taken which is exposed to the hot gases on one side and to the water on the other. A safe rule, and the one by which Table XII is computed, is to take ½ the area of the shell, ⅔ of the rear head, less the tube area, and the interior surface of all the tubes.

The required amount of grate area, and the proper ratio of heat-

ing surface to grate area, vary a good deal, depending on the character of the fuel and on the chimney draft. By assuming the probable rates of combustion and evaporation, we may compute the required grate area for any boiler from the formula:

$$S = \frac{H.P. \times 34.5}{E \times C},$$

in which

S = Total grate area, in square feet;

E = Pounds of water evaporated per pound of coal;

C = Pounds of coal burned per square foot of grate per hour.

Table XI gives the approximate grate area per H. P. for different rates of evaporation and combustion as computed by the above equation.

TABLE XI

Grate Area per Horse-Power for Different Rates of Evaporation and Combustion

Pounds of Steam per Pound of Coal	Pounds of Coal Burned per Square Foot of Grate per Hour		
	8 lbs.	10 lbs.	12 lbs.
	Square Feet of Grate Surface per Horse-Power		
10	.43	.35	.28
9	.48	.38	.32
8	.54	.43	.36
7	.62	.49	.41
6	.72	.58	.48

For example, with an evaporation of 8 pounds of steam per pound of coal, and a combustion of 10 pounds of coal per square foot of grate, .43 of a square foot of grate surface per H. P. would be called for.

The ratio of heating to grate surface in this type of boiler ranges from 30 to 40, and therefore allows under ordinary conditions a combustion of from 8 to 10 pounds of coal per square foot of grate. This is easily obtained with a good chimney draft and careful firing. The larger the boiler, the more important the plant usually, and the greater the care bestowed upon it, so that we may generally count on a higher rate of combustion and a greater efficiency as the size of the boiler increases. Table XII will be found very useful in determining the size of boiler required under different conditions. The grate area is computed for an evaporation of 8 pounds of water per pound

TABLE XII

Diameter of Shell in Inches	Number of Tubes	Diameter of Tubes in Inches	Length of Tubes in Feet	Horse-Power	Size of Grate in Inches	Size of Uptake in Inches	Size of Smoke-pipe in Sq. In.
30	28	2½	6	8.5	24 x 36	10 x 14	140
			7	9.9	24 x 36	10 x 14	140
			8	11.2	24 x 36	10 x 14	140
			9	12.6	24 x 42	10 x 14	140
			10	14.0	24 x 42	10 x 14	140
36	34	2½	8	13.6	30 x 36	10 x 16	160
			9	15.3	30 x 42	10 x 18	180
			10	16.9	30 x 42	10 x 18	180
			11	18.6	30 x 48	10 x 20	200
			12	20.9	30 x 48	10 x 20	200
42	34	3	9	18.5	36 x 42	10 x 20	200
			10	20.5	36 x 42	10 x 20	200
			11	22.5	36 x 48	10 x 25	250
			12	24.5	36 x 48	10 x 25	250
			13	26.5	36 x 48	10 x 28	280
			14	28.5	36 x 54	10 x 28	280
48	44	3	10	30.4	42 x 48	10 x 28	280
			11	33.2	42 x 48	10 x 28	280
			12	35.7	42 x 54	10 x 32	320
			13	38.3	42 x 54	10 x 32	320
			14	40.8	42 x 60	10 x 36	360
			15	43.4	42 x 60	10 x 36	360
			16	45.9	42 x 60	10 x 36	360
54	54	3	11	34.6	48 x 54	10 x 38	380
			12	37.7	48 x 54	10 x 38	380
			13	40.8	48 x 54	10 x 38	380
			14	43.9	48 x 54	10 x 38	380
			15	47.0	48 x 60	10 x 40	400
			16	50.1	48 x 60	10 x 40	400
	46	3½	17	53.0	48 x 60	10 x 40	400
60	72	3	12	48.4	54 x 60	12 x 40	460
			13	52.4	54 x 60	12 x 40	460
			14	56.4	54 x 60	12 x 40	460
			15	60.4	54 x 66	12 x 42	500
			16	64.4	54 x 66	12 x 42	500
	64	3½	17	71.4	54 x 72	12 x 48	550
			18	75.6	54 x 72	12 x 48	550
66	90	3	14	70.1	60 x 66	12 x 48	500
			15	75.0	60 x 72	12 x 52	620
			16	80.0	60 x 72	12 x 52	620
	78	3½	17	86.0	60 x 78	12 x 56	670
			18	91.1	60 x 78	12 x 56	670
			19	96.2	60 x 78	12 x 56	670
	62	4	20	93.1	60 x 78	12 x 56	670
72	114	3	14	87.4	66 x 72	12 x 56	670
			15	93.6	66 x 72	12 x 56	670
			16	99.7	66 x 78	12 x 62	740
	98	3½	17	106.4	66 x 78	12 x 62	740
			18	112.6	66 x 84	12 x 66	790
			19	118.8	66 x 84	12 x 66	790
	72	4	20	107.3	66 x 84	12 x 66	790

of coal, which corresponds to an efficiency of about 60 per cent, and is about the average obtained in practice for heating boilers.

The areas of uptake and smoke-pipe are figured on a basis of 1 square foot to 7 square feet of grate surface, and the results given in round numbers. In the smaller sizes the relative size of smoke-pipe is greater. The rate of combustion runs from 6 pounds in the smaller sizes to 11½ in the larger. Boilers of the proportions given in the table, correspond well with those used in actual practice, and may be relied upon to give good results under all ordinary conditions.

Water-tube boilers are often used for heating purposes, but more especially in connection with power plants. The method of computing the required H. P. is the same as for tubular boilers.

Sectional Boilers. Fig. 13 shows a common form of cast-iron boiler. It is made up of slabs or sections, each one of which is connected by nipples with headers at the sides and top. The top header acts as a steam drum, and the lower ones act as mud drums; they also receive the water of condensation from the radiators. The gases from the fire pass backward and forward through flues and are finally taken off at the rear of the boiler.

Another common form of sectional boiler is shown in Fig. 14. It is made up of sections which increase the length like the one just described. These boilers have no drum connecting with the sections; but instead, each section connects with the adjacent one through openings at the top and bottom, as shown.

The ratio of heating to grate surface in boilers of this type ranges from 15 to 25 in the best makes. They are provided with the usual attachments, such as pressure-gauge, water-glass, gauge-cocks, and safety-valve; a low-pressure damper regulator is furnished for operating the draft doors, thus keeping the steam pressure practically constant. A pressure of from 1 to 5 pounds is usually carried on these boilers, depending upon the outside temperature. The usual setting is simply a covering of some kind of non-conducting material like plastic magnesia or asbestos, although some forms are enclosed in light brickwork.

In computing the required size, we may proceed in the same manner as in the case of a furnace. For the best types of house-heating boilers, we may assume a combustion of 5 pounds of coal per square foot of grate per hour, and an average efficiency of 60 per cent,

which corresponds to 8,000 B. T. U. per pound of coal, available for useful work.

In the case of direct-steam heating, we have only to supply heat to offset that lost by radiation and conduction; so that the grate area may be found by dividing the computed heat loss per hour by 8,000, which gives the number of pounds of coal; and this in turn, divided by 5, will give the area of grate required. The most efficient rate of

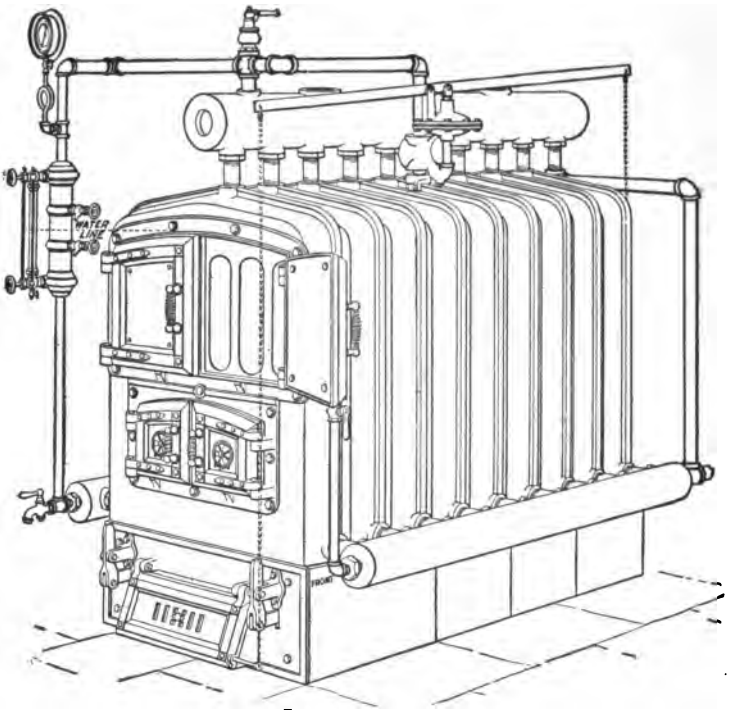


Fig. 13. Common Type of Cast-Iron Sectional Boiler. Note Headers at Sides and Top Acting as Drums.

combustion will depend somewhat upon the ratio between the grate and heating surface. It has been found by experience that about $\frac{1}{4}$ of a pound of coal per hour for each square foot of heating surface gives the best results; so that, by knowing the ratio of heating surface to grate area for any make of heater, we can easily compute the most efficient rate of combustion, and from it determine the necessary grate area.

For example, suppose the heat loss from a building to be 480,000 B. T. U. per hour, and that we wish to use a heater in which the ratio of heating surface to grate area is 24. What will be the most efficient rate of combustion and the required grate area? $480{,}000 \div 8{,}000 = 60$ pounds of coal per hour, and $24 \div 4 = 6$, which is the best rate of combustion to employ; therefore $60 \div 6 = 10$, the grate area required.

Fig. 14. Ideal Sectional 36-Inch Steam Boiler.
Courtesy of American Radiator Company.

There are many different designs of cast-iron boilers for low-pressure steam and hot-water heating. In general, boilers having a drum connected by nipples with each section give dryer steam and hold a steadier water-line than the second form, especially when forced above their normal capacity. The steam, in passing through the openings between successive sections in order to reach the outlet, is apt to carry with it more or less water, and to choke the openings, thus producing an uneven pressure in different parts of the boiler.

In the case of hot-water boilers this objection disappears.

For steam work the opening between the sections should be of good size, with an ample steam space above the water-line; and the nozzles for the discharge of steam should be located at frequent intervals.

EXAMPLES FOR PRACTICE

1. The heat loss from a building is 240,000 B. T. U. per hour, and the ratio of heating to grate area in the heater to be used is 20. What will be the required grate area? Ans. 6 sq. ft.

2. The heat loss from a building is 168,000 B. T. U. per hour, and the chimney draft is such that not over 3 pounds of coal per hour can be burned per square foot of grate. What ratio of heating to grate area will be necessary, and what will be the required grate area?

Ans. Ratio, 12. Grate area, 7 sq. ft.

Cast-iron sectional boilers are used for dwelling-houses, small schoolhouses, churches, etc., where low pressures are carried. They are increased in size by adding more slabs or sections. After a certain length is reached, the rear sections become less and less efficient, thus limiting the size and power.

Horse-Power for Ventilation. We already know that one B. T. U. will raise the temperature of 1 cubic foot of air 55 degrees, or it will raise 100 cubic feet $\frac{1}{100}$ of 55 degrees, or $\frac{55}{100}$ of 1 degree; therefore, to raise 100 cubic feet 1 degree, it will take $1 \div \frac{55}{100}$, or $\frac{100}{55}$ B. T. U.; and to raise 100 cubic feet through 100 degrees, it will take $\frac{100}{55} \times 100$ B. T. U. In other words, the B. T. U. required to raise any given volume of air through any number of degrees in temperature, is equal to

$$\frac{\text{Volume of air in cubic ft.} \times \text{Degrees raised}}{55}$$

Example. How many B. T. U. are required to raise 100,000 cubic feet of air 70 degrees?

$$\frac{100{,}000 \times 70}{55} = 127{,}272 +$$

To compute the H. P. required for the ventilation of a building, we multiply the total air-supply, in cubic feet per hour, by the number of degrees through which it is to be raised, and divide the result by 55. This gives the B. T. U. per hour, which, divided by 33,000, will give the H. P. required. In using this rule, always take the air-supply in cubic feet per *hour*.

EXAMPLES FOR PRACTICE

1. The heat loss from a building is 1,650,000 B. T. U. per hour. There is to be an air-supply of 1,500,000 cubic feet per hour, raised through 70 degrees. What is the total boiler H. P. required?

ANS. 108.

2. A high school has 10 classrooms, each occupied by 50 pupils. Air is to be delivered to the rooms at a temperature of 70 degrees. What will be the total H. P. required to heat and ventilate the building when it is 10 degrees below zero, if the heat loss through walls and windows is 1,320,000 B. T. U. per hour? ANS. 106+.

DIRECT-STEAM HEATING

A system of direct-steam heating consists (1) of a furnace and

boiler for the combustion of fuel and the generation of steam; (2) a system of pipes for conveying the steam to the radiators and for returning the water of condensation to the boiler; and (3) radiators or coils placed in the rooms for diffusing the heat.

Various types of boilers are used, depending upon the size and kind of building to be warmed. Some form of cast-iron sectional boiler is commonly used for dwelling-houses, while the tubular or water-tube boiler is more usually employed in larger buildings. Where the boiler is used for heating purposes only, a low steam-pressure of from 2 to 10 pounds is carried, and the condensation flows back by gravity to the boiler, which is placed below the lowest radiator. When, for any reason, a higher pressure is required, the steam for the heating system is made to pass through a reducing valve, and the condensation is returned to the boiler by means of a pump or return trap.

Fig. 15. Peerless 2-Column Cast-Iron Radiator. *Courtesy of American Radiator Company, Chicago.*

Types of Radiating Surface. The radiation used in direct-steam heating is made up of cast-iron radiators of various forms, of pipe radiators, and of circulation coils.

Cast-Iron Radiators. The general form of a cast-iron sectional radiator is shown in Fig. 15. Radiators of this type are made up of sections, the number depending upon the amount of heating surface required. Fig. 16 shows an intermediate section of a radiator of this type. It is simply a loop with inlet and outlet at the bottom. The end sections are the same, except that they have legs, as shown in Fig. 17. These sections are connected at the bottom by special nipples, so that steam entering at the end fills the bottom of the radiator, and, being lighter than the air, rises through the loops and forces the air downward and toward the farther end, where it is discharged through an air-valve placed about midway of the last section. For one-pipe steam work the *supply-leg* section is constructed with low-drip hub, and for two-pipe steam work, the *return-leg* section is constructed with low-drip hub.

There are many designs varying in height and width, to

suit all conditions. The wall pattern shown in Fig. 18 is very convenient when it is desired to place the radiator above the floor, as in bathrooms, etc.; it is also a convenient form to place under the windows of halls and churches to counteract the effect of cold down drafts. It is adapted to nearly every place where the ordinary direct radiator can be used, and may be connected up in different ways to meet the various requirements.

Fig. 16.

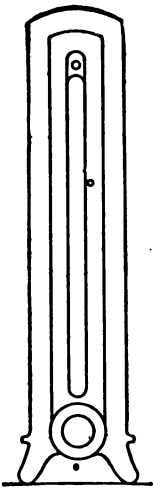


Fig. 17.

Intermediate and End Sections of Radiator Shown in Fig. 15. The end sections (at right) have legs.

A low and moderately shallow radiator, with ample space for the circulation of air between the sections, is more efficient than a deep radiator with the sections closely packed together. One- and two-column radiators, so called, are preferable to three- and four-column, when there is sufficient space to use them.

Fig. 18. Rococo Wall Radiators.
Courtesy of American Radiator Company, Chicago.

The standard height of a radiator is 36 or 38 inches, and, if possible, it is better not to exceed this.

For small radiators, it is better practice to use lower sections and increase the length; this makes the radiator slightly more efficient and gives a much better appearance.

To get the best results from wall radiators, they should be set out at least 1½ inches from the wall to allow a free circulation of air back of them. Patterns having cross-bars should be placed, if possible, with the bars in a vertical position, as their efficiency is impaired somewhat when placed horizontally.

Pipe Radiators. This type of radiator (see Fig. 19) is made up of wrought-iron pipes screwed into a cast-iron base. The pipes are either connected in pairs at the top by return bends, or each separate tube has a thin metal diaphragm passing up the center nearly to the top. It is necessary that a loop be formed, else a "dead end" would occur. This would become filled with air and prevent steam from entering, thus causing portions of the radiator to remain cold.

Fig. 19. Wrought-Iron Pipe Radiator.

Circulation Coils. These are usually made up of 1 or 1¼-inch wrought-iron pipe, and may be hung on the walls of a room by means of hook plates, or suspended overhead on hangers and rolls.

Fig. 20 shows a common form for schoolhouse and similar work; this coil is usually made of 1¼-inch pipe screwed into *headers* or *branch tees* at the ends, and is hung on the wall just below the windows. This is known as a *branch coil.* Fig. 21 shows a *trombone coil,* which is commonly used when the pipes cannot turn a corner, and where the entire coil must be placed upon one side of the room. Fig. 22

is called a *miter coil*, and is used under the same conditions as a trombone coil if there is room for the vertical portion. This form is not so pleasing in appearance as either of the other two, and is found only in factories or shops, where looks are of minor importance.

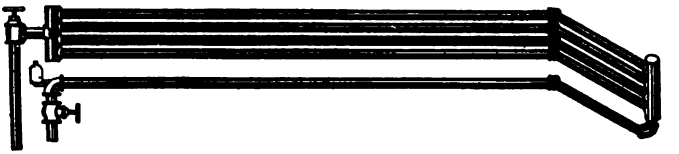


Fig. 20. Common Form of "Branch" Coil for Circulation of Direct Steam.

Overhead coils are usually of the miter form, laid on the side and suspended about a foot from the ceiling; they are less efficient than when placed nearer the floor, as the warm air stays at the ceiling and the lower part of the room is likely to remain cold. They are used

Fig. 21. "Trombone" Coil, Used where Entire Coil must be Placed on One Side of Room

only when wall coils or radiators would be in the way of fixtures, or when they would come below the water-line of the boiler if placed near the floor.

When steam is first turned on a coil, it usually passes through a

Fig. 22. "Miter" Coil. Adapted, like the "Trombone," Only to a Single Wall. Frequently Used in Factories and Shops.

portion of the pipes first and heats them while the others remain cold and full of air. Therefore the coil must always be made up in such a way that each pipe shall have a certain amount of spring and may expand independently without bringing undue strains upon the others. Circulation coils should incline about 1 inch in 20 feet toward the

return end in order to secure proper drainage and quietness of operation.

Efficiency of Radiators. The efficiency of a radiator—that is, the B. T. U. which it gives off per square foot of surface per hour—depends upon the difference in temperature between the steam in the radiator and the surrounding air, the velocity of the air over the radiator, and the quality of the surface, whether smooth or rough. In ordinary low-pressure heating, the first condition is practically constant; but the second varies somewhat with the pattern of the radiator. An open design which allows the air to circulate freely over the radiating surfaces, is more efficient than a closed pattern, and for this reason a pipe coil is more efficient than a radiator.

In a large number of tests of cast-iron and pipe radiators, working under usual conditions, the heat given off per square foot of surface per hour for each degree difference in temperature between the steam and surrounding air was found to average about 1.7 B. T. U. The temperature of steam at 3 pounds' pressure is 220 degrees, and 220—70 =150, which may be taken as the average difference between the temperature of the steam and the air of the room, in ordinary low-pressure work. Taking the above results, we have $150 \times 1.7 = 255$ B. T. U. as the efficiency of an average cast-iron or pipe radiator. This, for convenient use, may be taken as 250. A circulation coil made up of pipes from 1 to 2 inches in diameter, will easily give off 300 B. T. U. under the same conditions; and a cast-iron wall radiator with ample space back of it should have an efficiency equal to that of a wall coil. While overhead coils have a higher efficiency than cast-iron radiators, their position near the ceiling reduces their effectiveness, so that in practice the efficiency should not be taken over 250 B. T. U. per hour at the most. Tabulating the above we have:

TABLE XIII

Efficiency of Radiators, Coils, etc.

Type of Radiating Surface	Radiation per Square Foot of Surface per Hour
Cast-Iron Sectional and Pipe Radiators	250 B. T. U.
Wall Radiators	300 "
Ceiling Coils	200 to 250 "
Wall Coils	300 "

If the radiator is for warming a room which is to be kept at a temperature above or below 70 degrees, or if the steam pressure is greater than 3 pounds, the radiating surface may be changed in the same proportion as the difference in temperature between the steam and the air.

For example, if a room is to be kept at a temperature of 60°, the efficiency of the radiator becomes $\frac{1}{1}\frac{0}{5}\frac{7}{0} \times 250 = 267$; that is, the efficiency varies directly as the difference in temperature between the steam and the air of the room. It is not customary to consider this unless the steam pressure should be raised to 10 or 15 pounds or the temperature of the rooms changed 15 or 20 degrees from the normal.

From the above it is easy to compute the size of radiator for any given room. First compute the heat loss per hour by conduction and leakage in the coldest weather; then divide the result by the efficiency of the type of radiator to be used. It is customary to make the radiators of such size that they will warm the rooms to 70 degrees in the coldest weather. As the low-temperature limit varies a good deal in different localities, even in the same State, the lowest temperature for which we wish to provide must be settled upon before any calculations are made. In New England and through the Middle and Western States, it is usual to figure on warming a building to 70 degrees when the outside temperature is from zero to 10 degrees below.

The different makers of radiators publish in their catalogues, tables giving the square feet of heating surface for different styles and heights, and these can be used in determining the number of sections required for all special cases.

If pipe coils are to be used, it becomes necessary to reduce square feet of heating surface to linear feet of pipe; this can be done by means of the factors given below.

Square feet of heating surface $\times$

3	=	linear ft. of	1 -in.	pipe
2.3	=	" "	1¼-in.	"
2	=	" "	1½-in.	"
1.6	=	" "	2 -in.	"

The size of radiator is made only sufficient to keep the room warm after it is once heated; and no allowance is made for *warming up*; that is, the heat given off by the radiator is just equal to that lost through walls and windows. This condition is offset in two ways—

first, when the room is cold, the difference in temperature between the steam and the air of the room is greater, and the radiator is more efficient; and *second,* the radiator is proportioned for the coldest weather, so that for a greater part of the time it is larger than necessary.

EXAMPLES FOR PRACTICE

1. The heat loss from a room is 25,000 B. T. U. per hour in the coldest weather. What size of direct radiator will be required?

ANS. 100 square feet.

2. A schoolroom is to be warmed with circulation coils of 1¼-inch pipe. The heat loss is 30,000 B. T. U. per hour. What length of pipe will be required? ANS. 230 linear feet.

Location of Radiators. Radiators should, if possible, be placed in the coldest part of the room, as under windows or near outside doors. In living rooms it is often desirable to keep the windows free, in which case the radiators may be placed at one side. Circulation coils are run along the outside walls of a room under the windows. Sometimes the position of the radiators is decided by the necessary location of the pipe risers, so that a certain amount of judgment must be used in each special case as to the best arrangement to suit all requirements.

Systems of Piping. There are three distinct systems of piping, known as the *two-pipe system,* the *one-pipe relief system,* and the *one-pipe circuit system,* with various modifications of each and combinations of the different systems.

Fig. 23 shows the arrangement of piping and radiators in the two-pipe system. The steam main leads from the top of the boiler, and the branches are carried along near the basement ceiling. Risers are taken from the supply branches, and carried up to the radiators on the different floors; and return pipes are brought down to the return mains, which should be placed near the basement floor below the water-line of the boiler. Where the building is more than two stories high, radiators in similar positions on different floors are connected with the same riser, which may run to the highest floor; and a corresponding return drop connecting with each radiator is carried down beside the riser to the basement. A system in which the main horizontal returns are below the water-line of the boiler is said to

have a *wet* or *sealed* return. If the returns are overhead and above the water-line, it is called a *dry* return. Where the steam is exposed to extended surfaces of water, as in overhead returns, where the condensation partially fills the pipes, there is likely to be cracking or *water-hammer*, due to the sudden condensation of the steam as it comes in contact with the cooler water. This is especially noticeable when steam is first turned into cold pipes and radiators, and the condensation is excessive. When dry returns are used, the pipes should be large and have a good pitch toward the boiler.

In the case of sealed returns, the only contact between the steam

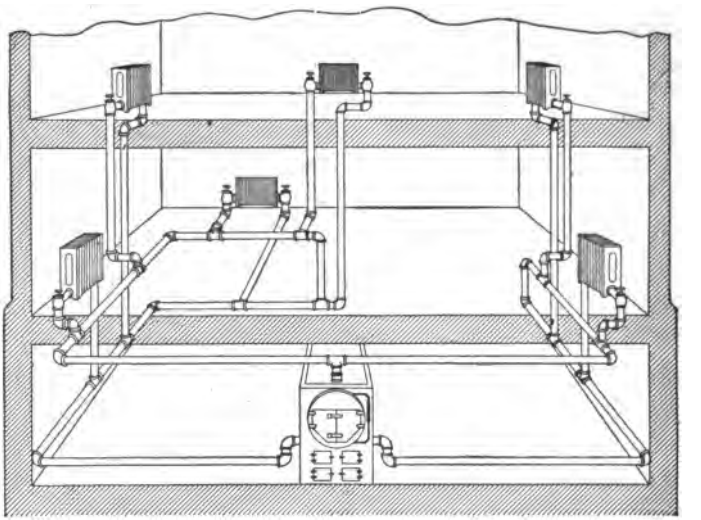


Fig. 23. Arrangement of Piping and Radiators in "Two-Pipe" System.

and standing water is in the vertical returns, where the exposed surfaces are very small (being equal to the sectional area of the pipes), and trouble from water-hammer is practically done away with. Dry returns should be given an incline of at least 1 inch in 10 feet, while for wet returns 1 inch in 20 or even 40 feet is ample. The ends of all steam mains and branches should be dripped into the returns. If the return is sealed, the drip may be directly connected as shown in Fig. 24; but if it is dry, the connection should be provided with a siphon loop as indicated in Fig. 25. The loop becomes filled with water, and prevents steam from flowing directly into the return. As the

condensation collects in the loop, it overflows into the return pipe and is carried away. The return pipes in this case are of course filled with steam above the water; but it is steam which has passed through the radiators and their return connections, and is therefore at a slightly lower pressure; so that, if steam were admitted directly from the main, it would tend to hold back the water in more distant returns and cause surging and cracking in the pipes. Sometimes the boiler is at a lower level than the basement in which the returns are run, and it then becomes necessary to establish a *false* water-line. This is done by making connections as shown in Fig. 26.

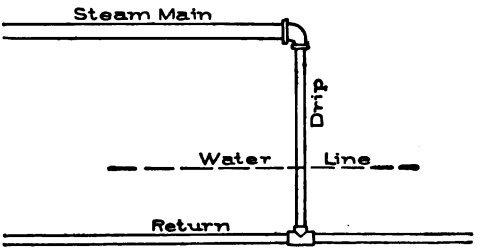


Fig. 24. Drip from Steam Main Connected Directly to Sealed Return.

It is readily seen that the return water, in order to reach the boiler, must flow through the trap, which raises the water-line or seal to the level shown by the dotted line. The balance pipe is to equalize the pressure above and below the water in the trap, and prevent siphonic action, which would tend to drain the water out of the return mains after a flow was once started.

The balance pipe, when possible, should be 15 or 20 feet in length, with a throttle-valve placed near its connection with the main. This valve should be opened just enough to allow the steam-pressure to act upon the air which occupies the space above the water in the trap; but it should not be opened sufficiently to allow the steam to enter in large volume and drive the air out. The success of this arrangement depends upon keeping a layer or cushion of cool air next to the surface of the water in the trap, and this is easily done by following the method here described.

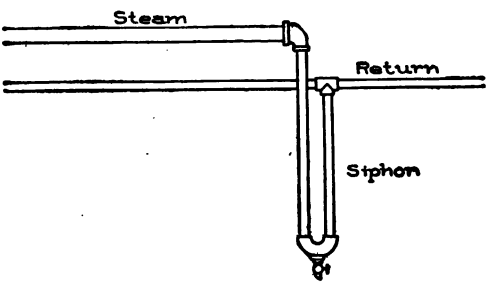


Fig. 25. Use of Siphon in Connecting Drip from Steam Main to a "Dry" Return.

One-Pipe Relief System. In this system of piping, the radiators have but a single connection, the steam flowing in and the condensation draining out through the same pipe. Fig. 27 shows the method of running the pipes for this system. The steam main, as before, leads from the top of the boiler, and is carried to as high a point as the basement ceiling will allow; it then slopes downward with a grade of about 1 inch in 10 feet, and makes a circuit of the building or a portion of it.

Risers are taken from the top and carried to the radiators above, as in the two-pipe system; but in this case, the condensation flows back through the same pipe, and drains into the return main near the floor through drip connections which are made at frequent intervals. In a two-story building, the bottom of each riser to the second floor is dripped; and in larger buildings, it is customary to drip each riser that has more than one radiator connected with it. If the radiators are large and at a considerable distance from the next riser, it is better to make a drip connection for each radiator. When the return main is overhead, the risers should be dripped through siphon loops; but the ends of the branches should make direct connection with the returns. This is the reverse of the two-pipe system. In this case the lowest pressure is at the ends of the mains, so that steam introduced into the returns at these points will cause no trouble in the pipes connecting between these and the boiler.

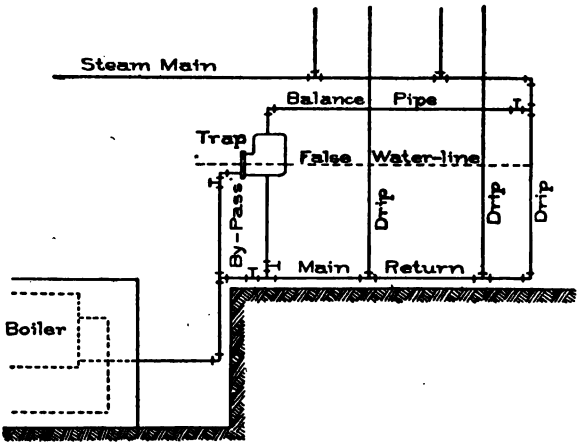


Fig. 26. Connections Made to Establish "False" Water-Line when Boiler is below Basement Level.

If no steam is allowed to enter the returns, a vacuum will be formed, and there will be no pressure to force the water back to the

boiler. A check-valve should always be placed in the main return

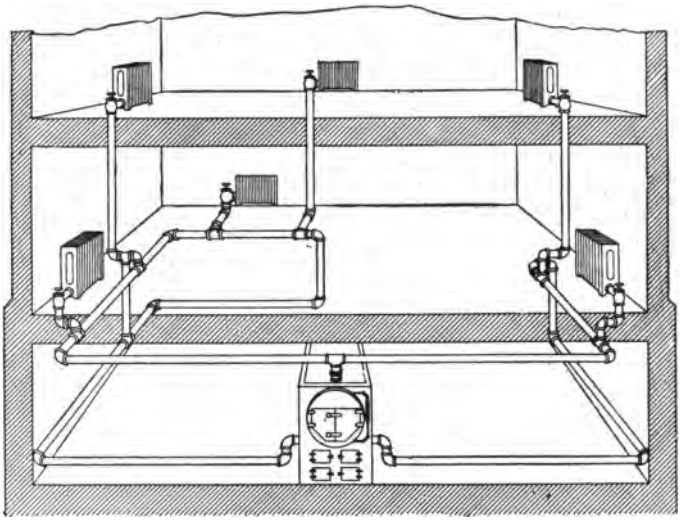


Fig. 27. Arrangement of Piping and Radiators in "One-Pipe Relief" System.

near the boiler, to prevent the water from flowing out in case of a vacuum being formed suddenly in the pipes.

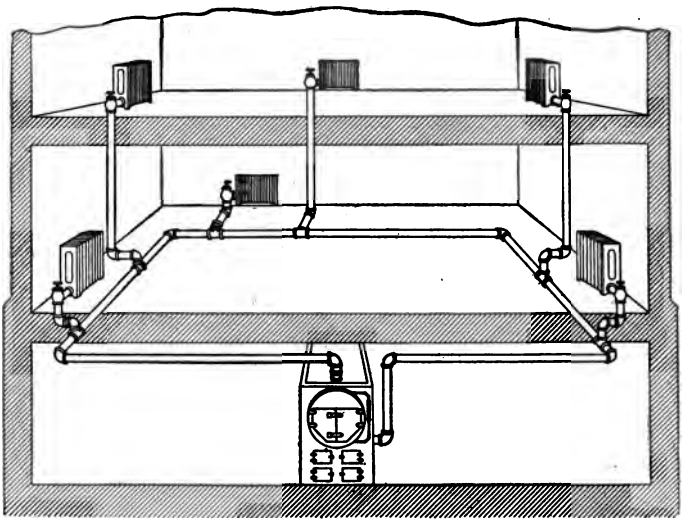


Fig. 28. Arrangement of Piping and Radiators in "One-Pipe Circuit" System.

There is but little difference in the cost of the two systems, as larger pipes and valves are required for the single-pipe method

With radiators of medium size and properly proportioned connections, the single-pipe system in preferable, there being but one valve to operate and only one-half the number of risers passing through the lower rooms.

One-Pipe Circuit System. In this case, illustrated in Fig. 28, the steam main rises to the highest point of the basement, as before; and then, with a considerable pitch, makes an entire circuit of the building, and again connects with the boiler below the water-line. Single risers are taken from the top; and the condensation drains back through the same pipes, and is carried along with the flow of steam to the extreme end of the main, where it is returned to the boiler. The main is made large, and of the same size throughout its entire length. It must be given a good pitch to insure satisfactory results.

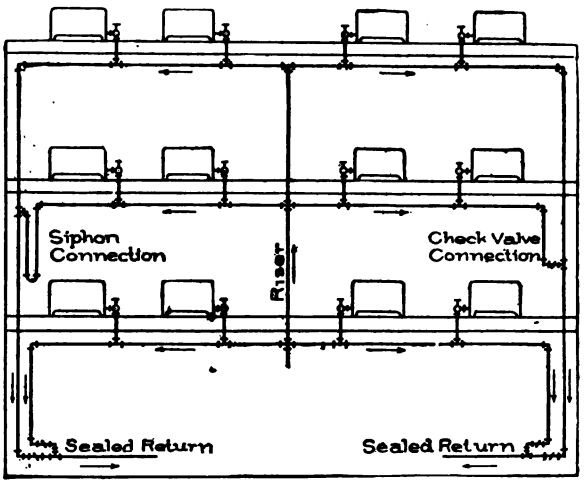


Fig. 29. "One-Pipe Circuit" System. Adapted to a Large Building.

One objection to a single-pipe system is that the steam and return water are flowing in opposite directions, and the risers must be made of extra large size to prevent any interference. This is overcome in large buildings by carrying a single riser to the attic, large enough to supply the entire building; then branching and running "drops" to the basement. In this system the flow of steam is downward, as well as that of water. This method of piping may be used with good results in two-pipe systems as well. Care must always be taken that no pockets or low points occur in any of the lines of pipe; but if for any reason they cannot be avoided, they should be carefully drained.

A modification of this system, adapting it to large buildings, is shown in diagram in Fig. 29. The riser shown in this case is one of

several, the number depending upon the size of the building; and may be supplied at either bottom or top as most desirable. If steam is supplied at the bottom of the riser, as shown in the cut, all of the drip connections with the return drop, except the upper one, should

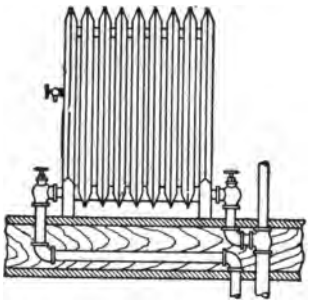


Fig. 30. "Two-Pipe" Connection of Radiator to Riser and Return.

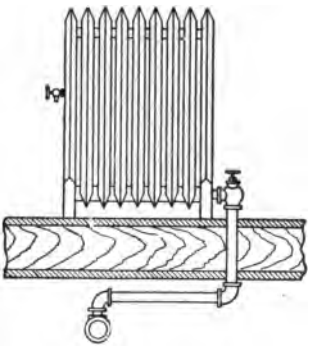


Fig. 31. "One-Pipe" Connection of Radiator to Basement Main.

be sealed with either a siphon loop or a check-valve, to prevent the steam from short-circuiting and holding back the condensation in the returns above. If an overhead supply is used, the arrangement should be the reverse; that is, all return connections should be sealed except the lowest.

Sometimes a separate drip is carried down from each set of radiators, as shown on the lower story, being connected with the main return below the water-line of the boiler. In case this is done, it is well to provide a check-valve in each drip below the water-line.

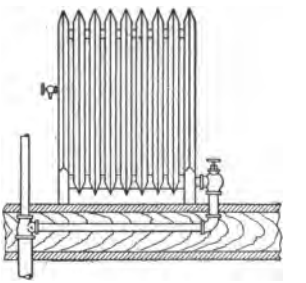


Fig. 32. "One-Pipe" Connection of Radiator to Riser.

In buildings of any considerable size, it is well to divide the piping system into sections by means of valves placed in the corresponding supply and return branches. These are for use in case of a break in any part of the system, so that it will be necessary to shut off only a small part of the heating system during repairs. In tall buildings, it is customary to place valves at the top and bottom of each riser, for the same purpose.

Radiator Connections. Figs. 30, 31, and 32 show the common

methods of making connections between supply pipes and radiators. Fig. 30 shows a two-pipe connection with a riser; the return is carried down to the main below. Fig. 31 shows a single-pipe connection with a basement main; and Fig. 32, a single connection with a riser.

Care must always be taken to make the horizontal part of the piping between the radiator and riser as short as possible, and to give it a good pitch toward the riser. There are various ways of making these connections, especially suited to different conditions; but the examples given serve to show the general principle to be followed.

Figs. 20, 21, and 22 show the common methods of making steam and return connections with circulation coils. The position of the air-valve is shown in each case.

Expansion of Pipes. Cold steam pipes expand approximately

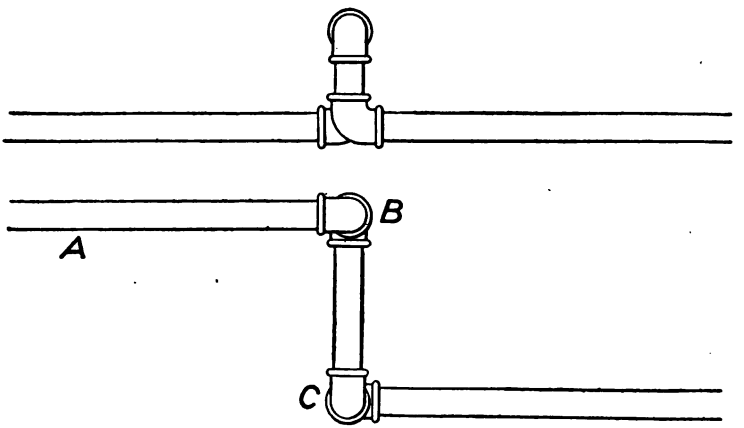


Fig. 33. Elevation and Plan of Swivel-Joint to Counteract Effects of Expansion and Contraction in Pipes.

1 inch in each 100 feet in length when low-pressure steam is turned into them; so that, in laying out a system of piping, we must arrange it in such a manner that there will be sufficient "spring" or "give" to the pipes to prevent injurious strains. This is done by means of offsets and bends. In the case of larger pipes this simple method will not be sufficient, and swivel or slip joints must be used to take up the expansion.

The method of making up a swivel-joint is shown in Fig. 33. Any lengthening of the pipe *A* will be taken up by slight turning or swivel movements at the points *B* and *C*. A slip-joint is shown in

Fig. 34. The part *c* slides inside the shell *d*, and is made steam-tight by a stuffing-box, as shown. The pipes are connected at the flanges *A* and *B*.

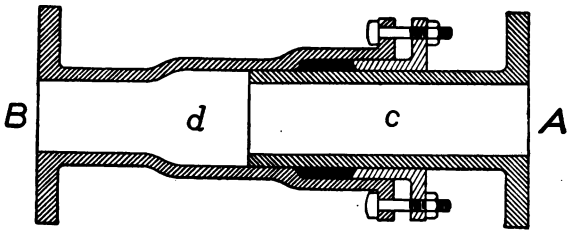


Fig. 34. "Slip-Joint" Connection to Take Care of Expansion and Contraction of Pipes.

When pipes pass through floors or partitions, the woodwork should be protected by galvanized-iron sleeves having a diameter from $\frac{3}{4}$ to 1 inch greater than the pipe. Fig. 35 shows a form of adjustable floor-sleeve which may be lengthened or shortened to conform to the thickness of floor or partition. If plain sleeves are used, a plate should be placed around the pipe where it passes through the floor or partition. These are made in two parts so that they may be put in place after the pipe is hung. A plate of this kind is shown in Fig. 36.

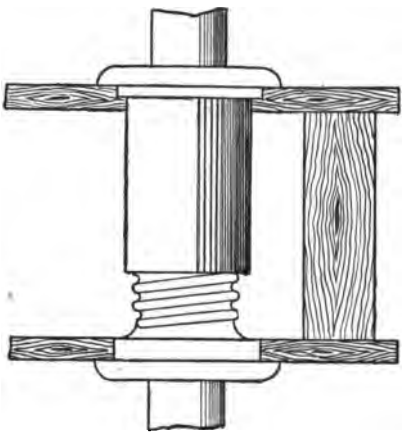


Fig. 35. Adjustable Metal Sleeve for Carrying Pipe through Floor or Partition.

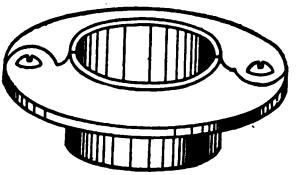


Fig. 36. Floor-Plate Adjusted to Plain Sleeve for Carrying Pipe through Floor or Partition.

Fig. 37. Angle Valve.

Fig. 38. Offset Valve.

Fig. 39. Corner Valve.

Valves for Radiator Connections.

Valves. The different styles commonly used for radiator connections are shown in Figs. 37, 38, and 39, and are known as *angle*, *offset*, and *corner* valves, respectively. The first is used when the radiator is at the top of a riser or when the connections are like those shown in Figs. 30, 31, and 32; the second is used when the connection

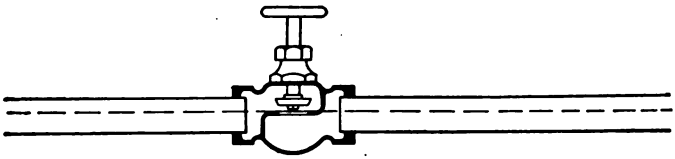


Fig. 40. Indicating Effect of Using Globe Valve on Horizontal Steam Supply Pipe or Dry Return.

between the riser and radiator is above the floor; and the third, when the radiator has to be set close in the corner of a room and there is not space for the usual connection.

A *globe* valve should never be used in a horizontal steam supply or dry return. The reason for this is plainly shown in Fig. 40. In order for water to flow through the valve, it must rise to a height shown by the dotted line, which would half fill the pipes, and cause serious trouble from water-hammer. The gate valve shown in Fig. 41 does not have this undesirable feature, as the opening is on a level with the bottom of the pipe.

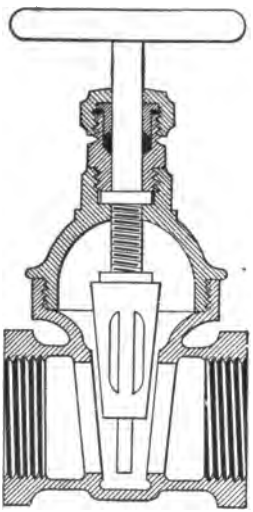


Fig. 41. Gate Valve.

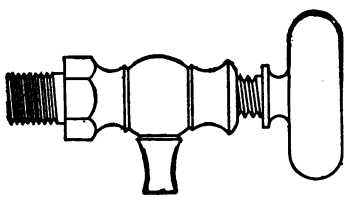


Fig. 42. Simplest Form of Air-Valve. Operated by Hand.

Air-Valves. Valves of various kinds are used for freeing the radiators from air when steam is turned on. Fig. 42 shows the simplest form, which is operated by hand. Fig. 43 is a type of automatic valve, consisting of a shell, which is attached to the radiator. *E* is a small opening which may be closed by the spindle *C*, which

is provided with a conical end. *D* is a strip composed of a layer of iron or steel and one of brass soldered or brazed together. The action of the valve is as follows: when the radiator is cold and filled with air the valve stands as shown in the cut. When steam is turned on, the air is driven out through the opening *B*. As soon as this is expelled and steam strikes the strip *D*, the two prongs spring apart owing to the unequal expansion of the two metals due to the heat of the steam. This raises the spindle *C*, and closes the opening so that no steam can escape. If air should collect in the valve, and the metal strip become cool, it would contract, and the spindle would drop and allow the air to escape through *B* as before. *E* is an adjusting nut. *F* is a float attached to the spindle, and is supposed, in case of a sudden rush of water with the air, to rise and close the opening; this action, however, is somewhat uncertain, especially if the pressure of water continues for some time.

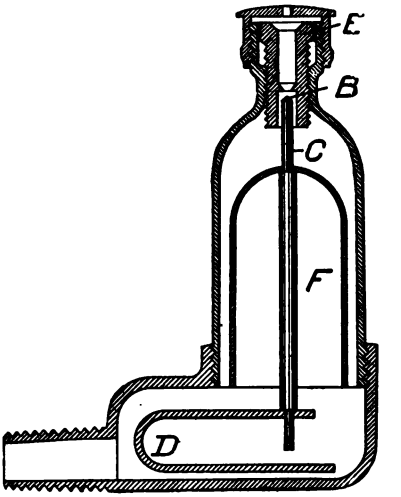


Fig. 43. Radiator Automatic Air-Valve, Operated by Metal Strip *D*, Consisting of Two Pieces of Metal of Unequal Expansive Power.

There are other types of valves acting on the same principle. The valve shown in Fig. 44 is closed by the expansion of a piece of vulcanite instead of a metal strip, and has no water float.

Fig. 44. Section of Jenkins Improved Automatic Air-Valve.

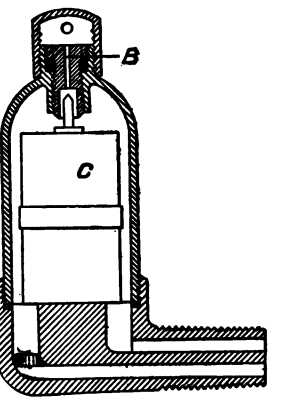


Fig. 45. Automatic Air-Valve Operated by Expansion of Drum *C* Due to Vaporization of Alcohol with which it is Partly Filled.

The valve shown in Fig. 45 acts on a somewhat different principle. The float *C* is made of thin brass, closed at top and bottom, and is partially filled with wood alcohol. When steam strikes the float, the alcohol is vaporized, and creates a pressure sufficient to bulge out the ends slightly, which raises the spindle and closes the opening *B*.

Fig. 46 shows a form of so-called *vacuum valve*. It acts in a similar manner to those already described, but has in addition a ball check which prevents the air from being drawn into the radiator, should the steam go down and a vacuum be formed. If a partial vacuum exists in the boiler and radiators, the boiling point, and consequently the temperature of the steam, are lowered, and less heat is given off by the radiators. This method of operating a heating plant is sometimes advocated for spring and fall, when little heat is required, and when steam under pressure would overheat the rooms.

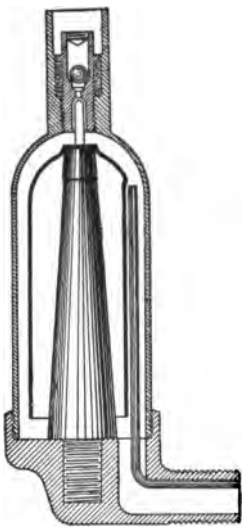


Fig. 46. Vacuum Valve.

Pipe Sizes. The proportioning of the steam pipes in a heating plant is of the greatest importance, and should be carefully worked out by methods which experience has proved to be correct. There are several ways of doing this; but for ordinary conditions, Tables XIV, XV, and XVI have given excellent results in actual practice. They have been computed from what is known as D'Arcy's formula, with suitable corrections made for actual working conditions. As the computations are somewhat complicated, only the results will be given here, with full directions for their proper use.

Table XIV gives the flow of steam in pounds per minute for pipes of different diameters and with varying drops in pressure between the supply and discharge ends of the pipe. These quantities are for pipes 100 feet in length; for other lengths the results must be corrected by the factors given in Table XVI. As the length of pipe increases, friction becomes greater, and the quantity of steam discharged in a given time is diminished.

Table XIV is computed on the assumption that the drop in

TABLE XIV

Flow of Steam in Pipes of Various Sizes, with Various Drops in Pressure between Supply and Discharge Ends

Calculated for 100-Foot Lengths of Pipe

Diam. of Pipe	Drop in Pressure (Pounds)								
	¼	½	¾	1	1½	2	3	4	5
1	.44	.63	.78	91	1.13	1.31	1.66	1.97	2.26
1¼	.81	1.16	1.43	1.66	2.05	2.39	3.02	3.59	4.12
1½	1.06	1.89	2.34	2.71	3.36	3.92	4.94	5.88	6.75
2	2.93	4.17	5.16	5.99	7.43	8.65	10.9	13.0	14.9
2½	5.29	7.52	9.32	10.8	13.4	15.6	19.7	23.4	26.9
3	8.61	12.3	15.2	17.6	21.8	25.4	32	31.8	43.7
3½	12.9	18.3	22.6	26.3	32.5	37.9	47.8	56.9	65.3
4	18.1	25.7	31.8	36.9	45.8	53.3	67.2	80.1	91.9
5	32.2	45.7	56.6	65.7	81.3	94.7	120	142	163
6	51.7	73.3	90.9	106	131	152	192	229	262
7	76.7	109	135	157	194	226	285	339	390
8	108	154	190	222	274	319	402	478	549
9	147	209	258	299	371	432	545	649	745
10	192	273	339	393	487	567	715	852	977
12	305	434	537	623	771	899	1,130	1,350	1,550
15	535	761	942	1,090	1,350	1,580	1,990	2,370	2,720

pressure between the two ends of the pipe equals the initial pressure. If the drop in pressure is less than the initial pressure, the actual discharge will be slightly greater than the quantities given in the table;

TABLE XV

Factors for Calculating Flow of Steam in Pipes under Initial Pressures above Five Pounds

To be used in connection with Table XIV

Drop in Pressure in Pounds	Initial Pressure (Pounds)					
	10	20	30	40	60	80
¼	1.27	1.49	1.68	1.84	2.13	2.38
½	1.26	1.48	1.66	1.83	2.11	2.36
1	1.24	1.46	1.64	1.80	2.08	2.32
2	1.21	1.41	1.59	1.75	2.02	2.26
3	1.17	1.37	1.55	1.70	1.97	2.20
4	1.14	1.34	1.51	1.66	1.92	2.14
5	1.12	1.31	1.47	1.62	1.87	2.09

but this difference will be small for pressures up to 5 pounds, and may be neglected, as it is on the side of safety. For higher initial pressures, Table XV has been prepared. This is to be used in connection with Table XIV as follows: First find from Table XIV the quantity of steam which will be discharged through the given diameter of pipe

TABLE XVI

Factors for Calculating Flow of Steam in Pipes of Other Lengths than 100 Feet

Feet	Factor	Feet	Factor	Feet	Factor	Feet	Factor
10	3.16	120	.91	275	.60	600	.40
20	2.24	130	.87	300	.57	650	.39
30	1.82	140	.84	325	.55	700	.37
40	1.58	150	.81	350	.53	750	.36
50	1.41	160	.79	375	.51	800	.35
60	1.29	170	.76	400	.50	850	.34
70	1.20	180	.74	425	.48	900	.33
80	1.12	190	.72	450	.47	950	.32
90	1.05	200	.70	475	.46	1,000	.31
100	1.00	225	.66	500	.45		
110	.95	250	.63	550	.42		

with the assumed drop in pressure; then look in Table XV for the factor corresponding with the assumed drop and the higher initial pressure to be used. The quantity given in Table XIV, *multiplied by* this factor, will give the actual capacity of the pipe under the given conditions.

Example—What weight of steam will be discharged through a 3-inch pipe 100 feet long, with an initial pressure of 60 pounds and a drop of 2 pounds?

Looking in Table XIV, we find that a 3-inch pipe will discharge 25.4 pounds of steam per minute with a 2-pound drop. Then looking in Table XV, we find the factor corresponding to 60 pounds initial pressure and a drop of 2 pounds to be 2.02. Then according to the rule given, $25.4 \times 2.02 = 51.3$ pounds, which is the capacity of a 3-inch pipe under the assumed conditions.

Sometimes the problem will be presented in the following way: What size of pipe will be required to deliver 80 pounds of steam a distance of 100 feet with an initial pressure of 40 pounds and a drop of 3 pounds?

We have seen that the higher the initial pressure with a given drop, the greater will be the quantity of steam discharged; therefore a smaller pipe will be required to deliver 80 pounds of steam at 40 pounds than at 3 pounds initial pressure From Table XV, we find that a given pipe will discharge 1.7 times as much steam per minute with a pressure of 40 pounds and a drop of 3 pounds, as it would with a pressure of 3 pounds, dropping to zero. From this it is evident that if we divide 80 by 1.7 and look in Table XIV under "3 pounds

drop" for the result thus obtained, the size of pipe corresponding will be that required. Now, $80 \div 1.7 = 47$. The nearest number in the table marked "3 pounds drop" is 47.8, which corresponds to a $3\frac{1}{2}$-inch pipe, which is the size required.

These conditions will seldom be met with in low-pressure heating, but apply more particularly to combination power and heating plants, and will be taken up more fully under that head. For lengths of pipe other than 100 feet, multiply the quantities given in Table XIV by the factors found in Table XVI.

Example--What weight of steam will be discharged per minute through a $3\frac{1}{2}$-inch pipe 450 feet long, with a pressure of 5 pounds and a drop of $\frac{1}{2}$ pound?

Table XIV, which may be used for all pressures below 10 pounds, gives for a $3\frac{1}{2}$-inch pipe 100 feet long, a capacity of 18.3 pounds for the above conditions. Looking in Table XVI, we find the correction factor for 450 feet to be .47. Then $18.3 \times .47 = 8.6$ pounds, the quantity of steam which will be discharged if the pipe is 450 feet long.

Examples involving the use of Tables XIV, XV, and XVI in combination, are quite common in practice. The following example will show the method of calculation:

What size of pipe will be required to deliver 90 pounds of steam per minute a distance of 800 feet, with an initial pressure of 80 pounds and a drop of 5 pounds?

Table XVI gives the factor for 800 feet as .35, and Table XV, that for 80 pounds pressure and 5 pounds drop, as 2.09. Then $\frac{90}{.35 \times 2.09} = 123$, which is the equivalent quantity we must look for in Table XIV. We find that a 4-inch pipe will discharge 91.9 pounds, and a 5-inch pipe 163 pounds. A $4\frac{1}{2}$-inch pipe is not commonly carried in stock, and we should probably use a 5-inch in this case, unless it was decided to use a 4-inch and allow a slightly greater drop in pressure. In ordinary heating work, with pressures varying from 2 to 5 pounds, a drop of $\frac{1}{4}$ pound in 100 feet has been found to give satisfactory results.

In computing the pipe sizes for a heating system by the above methods, it would be a long process to work out the size of each branch separately. Accordingly Table XVII has been prepared for ready use in low-pressure work.

As most direct heating systems, and especially those in schoolhouses, are made up of both radiators and circulation coils, an efficiency of 300 B. T. U. has been taken for direct radiation of whatever variety, no distinction being made between the different kinds. This gives a slightly larger pipe than is necessary for cast-iron radiators; but it is probably offset by bends in the pipes, and in any case gives a slight factor of safety. We find from a steam table that the *latent heat* of steam at 20 pounds above a vacuum (which corresponds to 5 pounds' gauge-pressure) is 954 + B. T. U.—which means that, for every pound of steam condensed in a radiator, 954 B. T. U. are given off for warming the air of the room. If a radiator has an efficiency of 300 B. T. U., then each square foot of surface will condense 300 ÷ 954 = .314 pound of steam per hour; so that we may assume in round numbers a condensation of $\frac{1}{3}$ of a pound of steam per hour for each square foot of direct radiation, when computing the sizes of steam pipes in low-pressure heating. Table XVII has been calculated on this assumption, and gives the square feet of heating surface

TABLE XVII

Heating Surface Supplied by Pipes of Various Sizes

Length of Pipe, 100 Feet

Size of Pipe	Square Feet of Heating Surface	
	¼ Pound Drop	½ Pound Drop
1	80	114
1¼	145	210
1½	190	340
2	525	750
2½	950	1,350
3	1,550	2,210
3½	2,320	3,290
4	3,250	4,620
5	5,800	8,220
6	9,320	13,200
7	13,800	19,620
8	19,440	27,720

which different sizes of pipe will supply, with drops in pressure of ¼ and ½ pounds in each 100 feet of pipe. The former should be used for pressures from 1 to 5 pounds, and the latter may be used for pressures over 5 pounds, under ordinary conditions. The sizes of long mains and special pipes of large size should be proportioned directly from Tables XIV, XV, and XVI.

Where the two-pipe system is used and the radiators have separate supply and return pipes, the risers or vertical pipes may be taken from Table XVII; but if the single-pipe system is used, the risers must be increased in size, as the steam and water are flowing in opposite directions and must have plenty of room to pass each other. It is customary in this case to base the computation on the velocity of the steam in the pipes, rather than on the drop in pressure. Assuming, as before, a condensation of one-third of a pound of steam per hour per square foot of radiation, Tables XVIII and XIX have been prepared for velocities of 10 and 15 feet per second. The sizes given in Table XIX have been found sufficient in most cases; but the larger sizes, based on a flow of 10 feet per second, give greater safety and should be more generally used. The size of the largest riser should usually be limited to $2\frac{1}{2}$ inches in school and dwelling-house work, unless it is a special pipe carried up in a concealed position. If the length of riser is short between the lowest radiator and the main, a higher velocity of 20 feet or more may be allowed through this portion, rather than make the pipe excessively large.

TABLE XVIII **TABLE XIX**

Radiating Surface Supplied by Steam Risers

10 Feet per Second Velocity		15 Feet per Second Velocity	
Size of Pipe	Sq. Feet of Radiation	Size of Pipe	Sq. Feet of Radiation
1 in.	30	1 in.	50
$1\frac{1}{4}$ "	60	$1\frac{1}{4}$ "	90
$1\frac{1}{2}$ "	80	$1\frac{1}{2}$ "	120
2 "	130	2 "	200
$2\frac{1}{2}$ "	190	$2\frac{1}{2}$ "	290
3 "	290	3 "	340
$3\frac{1}{2}$ "	390	$3\frac{1}{2}$ "	590

EXAMPLES FOR PRACTICE

1. How many pounds of steam will be delivered per minute, through a $3\frac{1}{2}$-inch pipe 600 feet long, with an initial pressure of 5 pounds and a drop of $\frac{1}{2}$ pound? Ans. 7.32 pounds.

2. What size pipe will be required to deliver 25.52 pounds of steam per minute with an initial pressure of 3 pounds and a drop of $\frac{1}{4}$ pound, the length of the pipe being 50 feet? Ans. 4-inch.

3. Compute the size of pipe required to supply 10,000 square feet of direct radiation (assume $\frac{1}{3}$ of a pound of steam per square

foot per hour) where the distance to the boiler house is 300 feet, and the pressure carried is 10 pounds, allowing a drop in pressure of 4 pounds. ANS. 5-inch (this is slightly larger than is required, while a 4-inch is much too small).

TABLE XX

Sizes of Returns for Steam Pipes (In Inches)

DIAMETER OF STEAM PIPE	DIAMETER OF DRY RETURN	DIAMETER OF SEALED RETURN
1	1	¾
1¼	1	1
1½	1¼	1
2	1½	1¼
2½	2	1½
3	2½	2
3½	2½	2
4	3	2½
5	3	2½
6	3½	3
7	3½	3
8	4	3½
9	5	3½
10	5	4
12	6	5

Returns. The size of return pipes is usually a matter of custom and judgment rather than computation. It is a common rule among steamfitters to make the returns one size smaller than the corresponding steam pipes. This is a good rule for the smaller sizes, but gives a larger return than is necessary for the larger sizes of pipe. Table XX gives different sizes of steam pipes with the corresponding diameters for dry and sealed returns.

TABLE XXI

Pipe Sizes for Radiator Connections

SQUARE FEET OF RADIATION		STEAM	RETURN
Two-Pipe	10 to 30	¾ inch	¾ inch
	30 to 48	1 "	¾ "
	48 to 96	1¼ "	1 "
	96 to 150	1½ "	1¼ "
Single-Pipe	10 to 24	1 inch	
	24 to 60	1¼ "	
	60 to 80	1½ "	
	80 to 130	2 "	

The length of run and number of turns in a return pipe should be noted, and any unusual conditions provided for. Where the condensation is discharged through a trap into a lower pressure, the sizes given may be slightly reduced, especially among the larger sizes, depending upon the differences in pressure.

Radiators are usually tapped for pipe connections as shown in Table XXI, and these sizes may be used for the connections with the mains or risers.

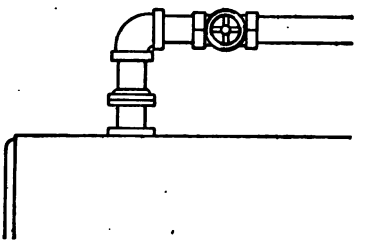


Fig 47. Good Position for Shut-Off Valve.

Boiler Connections. The steam main should be connected to the rear nozzle, if a tubular boiler is used, as the boiling of the water is less violent at this point and dryer steam will be obtained. The shut-off valve should be placed in such a position that pockets for the accumulation of condensation will be avoided. Fig. 47 shows a good position for the valve.

The size of steam connection may be computed by means of the methods already given, if desired. But for convenience the sizes given in Table XXII may be used with satisfactory results for the short runs between the boilers and main header.

TABLE XXII

Pipe Sizes from Boiler to Main Header

Diameter of Boiler	Size of Steam Pipe
36 inches	3 inches
42 "	4 "
48 "	4 "
54 "	5 "
60 "	5 "
66 "	6 "
72 "	6 "

The return connection is made through the blow-off pipe, and should be arranged so that the boiler can be blown off without draining the returns. A check-valve should be placed in the main return, and a plug-cock in the blow-off pipe. Fig. 48 shows in plan a good arrangement for these connections.

The feed connections, with the exception of that part exposed in the smoke-bonnet, are always made of brass in the best class of work. The small section referred to should be of extra heavy wrought

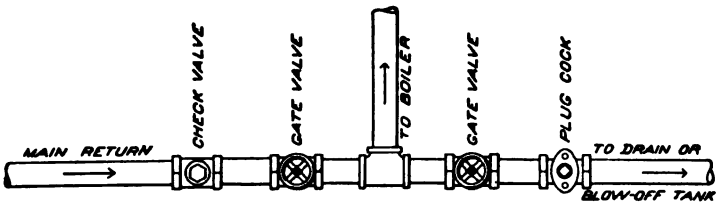


Fig. 48. A Good Arrangement of Return and Blow-Off Connections.

iron. The branch to each boiler should be provided with a gate or globe valve and a check-valve, the former being placed next to the boiler.

Table XXIII gives suitable sizes for return, blow-off, and feed pipes for boilers of different diameters.

TABLE XXIII

Sizes for Return, Blow-Off, and Feed Pipes

Diameter of Boiler	Size of Pipe for Gravity Return	Size of Blow-Off Pipe	Size of Feed Pipe
36 inches	1½ inches	1¼ inches	1 inch
42 "	2 "	1½ "	1 "
48 "	2 "	1½ "	1 "
54 "	2½ "	2 "	1¼ "
60 "	2½ "	2 "	1¼ "
66 "	3 "	2½ "	1¼ "
72 "	3 "	2½ "	1½ "

Blow-Off Tank. Where the blow-off pipe connects with a sewer, some means must be provided for cooling the water, or the expansion and contraction caused by the hot water flowing through the drain-pipes will start the joints and cause leaks. For this reason it is customary to pass the water through a blow-off tank. A form of wrought-iron tank is shown in Fig. 49. It consists of a receiver supported on cast-iron cradles. The tank ordinarily stands nearly full of cold water.

The pipe from the boiler enters above the water-line, and the sewer connection leads from near the bottom, as shown. A vapor pipe is carried from the top of the tank above the roof of the building. When water from the boiler is blown into the tank, cold water from

the bottom flows into the sewer, and the steam is carried off through the vapor pipe. The equalizing pipe is to prevent any siphon action which might draw the water out of the tank after a flow is once started. As only a part of the water is blown out of a boiler at one time, the blow-off tank can be of a comparatively small size. A tank 24 by 48 inches should be large enough for boilers up to 48 inches in diameter;

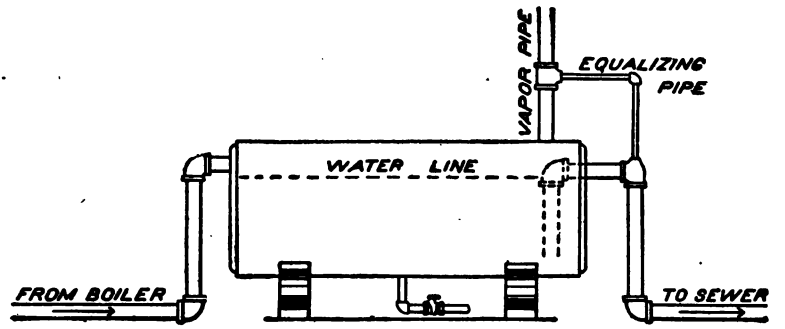
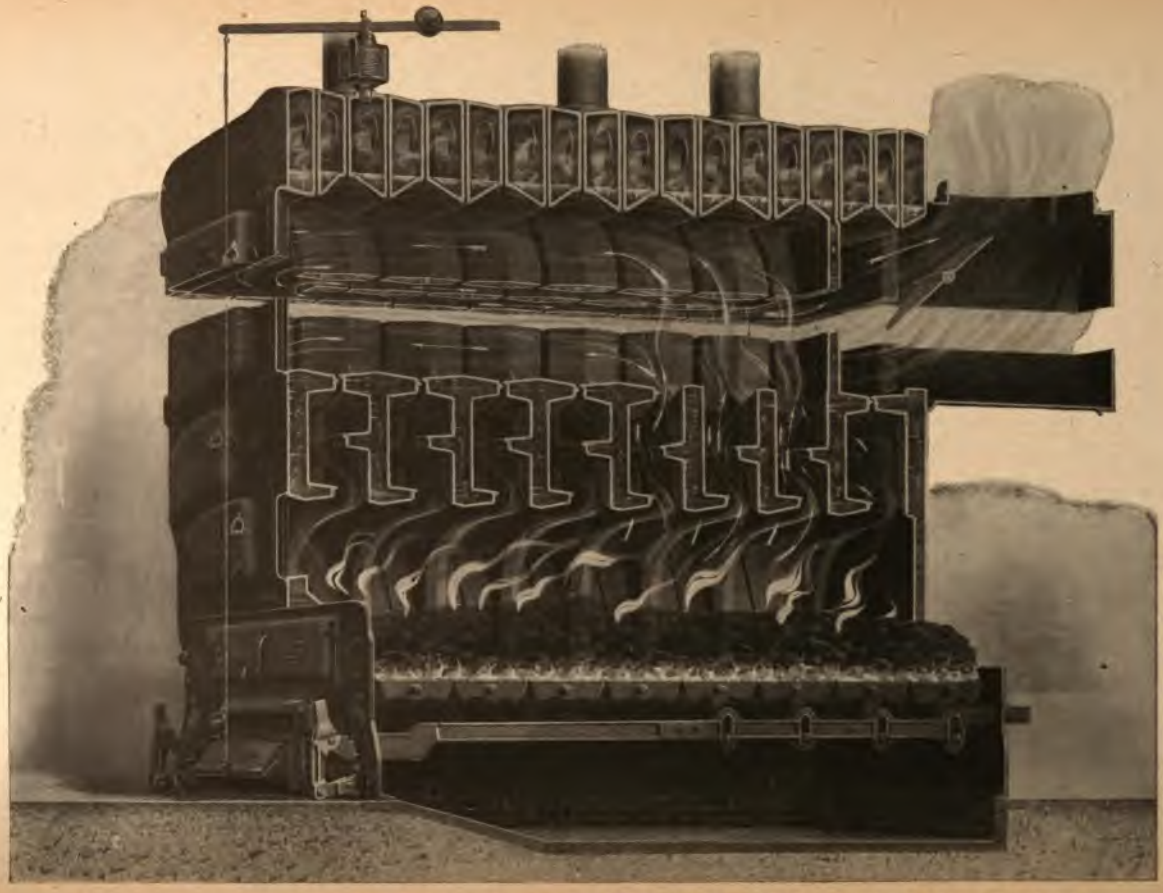


Fig. 49. Connections of Blow-Off Tank.

and one 36 by 72 inches should care for a boiler 72 inches in diameter. If smaller quantities of water are blown off at one time, smaller tanks can be used. The sizes given above are sufficient for batteries of 2 or more boilers, as one boiler can be blown off and the water allowed to cool before a second one is blown off. Cast-iron tanks are often used in place of wrought-iron, and these may be sunk in the ground if desirod.



IMAGINARY SECTIONAL VIEW OF IDEAL 48-INCH STEAM BOILER, SHOWING LARGE HEATING SURFACE

Courtesy of American Radiator Company, Chicago.

HEATING AND VENTILATION

PART II

INDIRECT STEAM HEATING

As already stated, in the indirect method of steam heating, a special form of heater is placed beneath the floor, and encased in galvanized iron or in brickwork. A cold-air box is connected with the space beneath the heater; and warm-air pipes at the top are connected with registers in the floors or walls as already described for furnaces. A separate heater may be provided for each register if the rooms are large, or two or more registers may be connected with the same heater if the horizontal runs of pipe are short. Fig. 50 shows a section through a heater arranged for introducing hot air into a room through a floor register; and Fig. 51 shows the same type of heater connected with a wall register. The cold-air box is seen at the bottom of the casing; and the air, in passing through the spaces between the sections of the heater, becomes warmed, and rises to the rooms above.

Different forms of indirect heaters are shown in Figs. 52 and 53. Several sections connected in a single group are called a *stack*. Sometimes the stacks are encased in brickwork built up from the basement floor, instead of in galvanized iron as shown in the cuts. This method of heating provides fresh air for ventilation, and for this reason is especially adapted for schoolhouses, hospitals, churches, etc. As compared with furnace heating, it has the advantage of being less affected by outside wind-pressure, as long runs of horizontal pipe

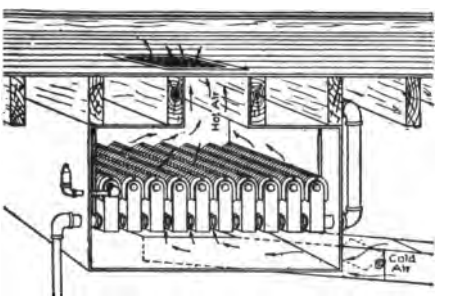


Fig. 50. Steam Heater Placed under Floor Register —Indirect System.

are avoided and the heaters can be placed near the registers. In a large building where several furnaces would be required, a single boiler can be used, and the number of stacks increased to suit the existing conditions, thus making it necessary to run but a single fire. Another advantage is the large ratio between the heating and grate surface as compared with a furnace; and as a result, a large quantity of air is warmed to a moderate temperature, in place of a smaller quantity heated to a much higher temperature. This gives a more agreeable quality to the air. Direct and indirect systems are often combined, in the living rooms, hallways and corridors, having only direct radiators for warming.

Fig. 51. Steam Heater Connected to Wall Register—Indirect System.
Courtesy of American Radiator Company, Chicago

Types of Heaters. Various forms of indirect radiators are shown in Figs. 52, 53, 54, and 56. A hot-water radiator may be used for steam; but a steam radiator cannot always be used for hot water, as

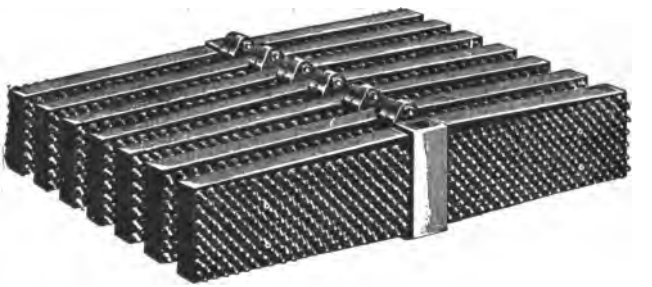


Fig. 52. One Form of Indirect Steam or Hot-Water Heater.

it must be especially designed to produce a continuous flow of water through it from top to bottom. Figs. 54 and 55 show the outside and the interior construction of a common pattern of indirect radiator

designed especially for steam. The arrows in Fig. 55 indicate the path of the steam through the radiator, which is supplied at the right, while the return connection is at the left. The air-valve in this case should be connected in the end of the last section near the return.

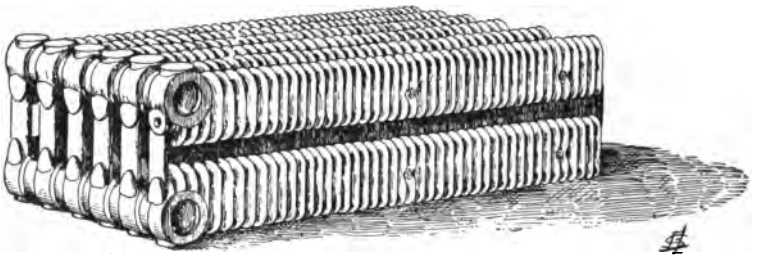


Fig. 53. Another Form of Indirect Steam or Hot-Water Heater.

A very efficient form of radiator, and one that is especially adapted to the warming of large volumes of air, as in schoolhouse work, is shown in Fig. 56, and is known as the *School pin* radiator. This can

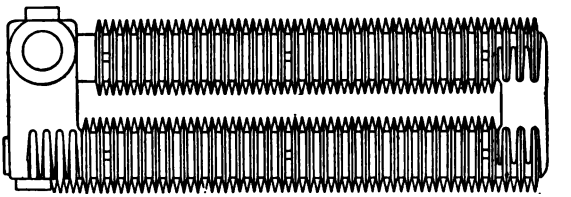


Fig. 54. Exterior View of a Common Type of Radiator for Indirect-Steam Heating.

be used for either steam or hot water, as there is a continuous passage downward from the supply connection at the top to the return at the bottom. These sections or slabs are made up in stacks after the

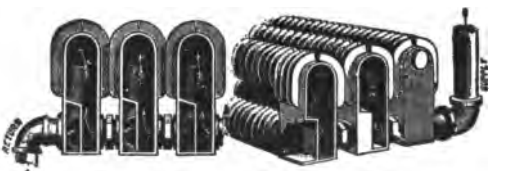


Fig. 55. Interior Mechanism of Radiator Shown in Fig. 54.

manner shown in Fig. 57, which represents an end view of several sections connected together with special nipples.

A very efficient form of indirect heater may be made up of wrought-iron pipe joined together with branch tees and return bends.

A heater like that shown in Fig. 58 is known as a *box coil.* Its efficiency is increased if the pipes are *staggered*—that is, if the pipes in alternate rows are placed over the spaces between those in the row below.

Efficiency of Heaters. The efficiency of an indirect heater

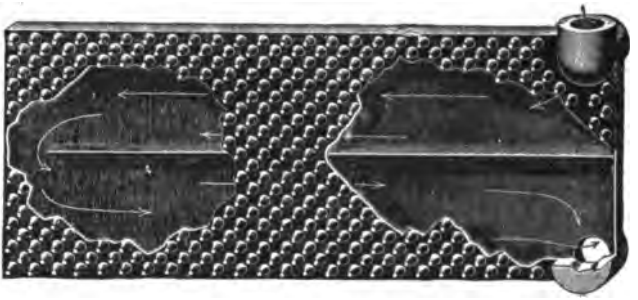


Fig. 56. "School Pin" Radiator, Especially Adapted for Warming Large Volumes of Air by Either Steam or Hot Water.

depends upon its form, the difference in temperature between the steam and the surrounding air, and the velocity with which the air passes over the heater. Under ordinary conditions in dwelling-house work, a good form of indirect radiator will give off about 2 B. T. U. per square foot per hour for each degree difference in temperature between the steam and the entering air. Assuming a steam pressure of 2 pounds and an outside temperature of zero, we should have a difference in temperature of about 220 degrees, which, under the conditions stated, would give an efficiency of 220 × 2 = 440 B. T. U. per hour for each square foot of radiation. By making a similar computation for 10 degrees below zero, we find the efficiency to be 460. In the same manner we may calculate the efficiency for varying conditions of steam pressure and outside temperature. In the case of schoolhouses and similar buildings where large volumes of air are warmed to a moderate tem-

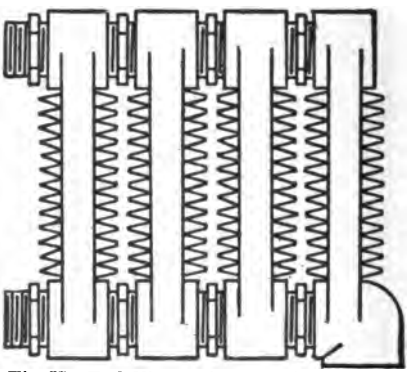


Fig. 57. End View of Several "School Pin" Radiator Sections Connected Together.

perature, a somewhat higher efficiency is obtained, owing to the increased velocity of the air over the heaters. Where efficiencies of 440 and 460 are used for dwellings, we may substitute 600 and 620 for schoolhouses. This corresponds approximately to 2.7 B. T. U. per square foot per hour for a difference of 1 degree between the air and steam.

The principles involved in indirect steam heating are similar to those already described in furnace heating. Part of the heat given off by the radiator must be used in warming up the air-supply to the temperature of the room, and part for offsetting the loss by conduction through walls and windows. The method of computing the heating surface required, depends upon the volume of air to be supplied to the room. In the case of a schoolroom or hall, where the air quantity

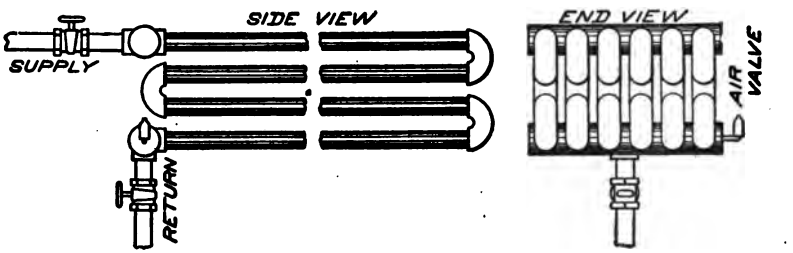


Fig. 58. "Box Coil," Built Up of Wrought-Iron Pipe, for Indirect-Steam Heating.

is large as compared with the exposed wall and window surface, we should proceed as follows:

First compute the B. T. U. required for loss by conduction through walls and windows; and to this, add the B. T. U. required for the necessary ventilation; and divide the sum by the efficiency of the radiators. An example will make this clear.

Example. How many square feet of indirect radiation will be required to warm and ventilate a schoolroom in zero weather, where the heat loss by conduction through walls and windows is 36,000 B. T. U., and the air-supply is 100,000 cubic feet per hour?

By the methods given under "Heat for Ventilation," we have

$$\frac{100{,}000 \times 70}{55} = 127{,}272 = \text{B. T. U. required for ventilation.}$$

$$36{,}000 + 127{,}272 = 163{,}272 \text{ B. T. U.} = \text{Total heat required.}$$

This in turn divided by 600 (the efficiency of indirect radiators under these conditions) gives 272 square feet of surface required.

In the case of a dwelling-house the conditions are somewhat changed, for a room having a comparatively large exposure will have perhaps only 2 or 3 occupants, so that, if the small air-quantity necessary in this case were used to convey the required amount of heat to the room, it would have to be raised to an excessively high temperature. It has been found by experience that the radiating surface necessary for indirect heating is about 50 per cent greater than that required for direct heating. So for this work we may compute the surface required for direct radiation, and multiply the result by 1.5.

Buildings like hospitals are in a class between dwellings and schoolhouses. The air-supply is based on the number of occupants, as in schools, but other conditions conform more nearly to dwelling-houses.

To obtain the radiating surface for buildings of this class, we compute the total heat required for warming and ventilation as in the case of schoolhouses, and divide the sum by the efficiencies given for dwellings—that is, 440 for zero weather, and 460 for 10 degrees below.

Example. A hospital ward requires 50,000 cubic feet of air per hour for ventilation; and the heat loss by conduction through walls, etc., is 100,000 B. T. U. per hour. How many square feet of indirect radiation will be required to warm the ward in zero weather?

$50{,}000 \times 70 \div 55 = 63{,}636$ B. T. U. for ventilation; then,

$$\frac{63{,}636 + 100{,}000}{440} = 372 + \text{square feet.}$$

EXAMPLES FOR PRACTICE

1. A schoolroom having 40 pupils is to be warmed and ventilated when it is 10 degrees below zero. If the heat loss by conduction is 30,000 B. T. U. per hour, and the air supply is to be 40 cubic feet per minute per pupil, how many square feet of indirect radiation will be required? ANS. 273.

2. A contagious ward in a hospital has 10 beds, requiring 6,000 cubic feet of air each, per hour. The heat loss by conduction in zero weather is 80,000 B. T. U. How many square feet of indirect radiation will be required? ANS. 355.

3. The heat loss from a sitting room is 11,250 B. T. U. per hour in zero weather. How many square feet of indirect radiation will be required to warm it? ANS. 67.5 sq. ft.

Stacks and Casings. It has already been stated that a group of sections connected together is called a stack, and examples of these with their casings are shown in Figs. 50 and 51. The casings are usually made of galvanized iron, and are made up in sections by means of small bolts so that they may be taken apart in case it is necessary to make repairs. Large stacks are often enclosed in brickwork, the sides consisting of 8-inch walls, and the top being covered over with a layer of brick and mortar supported on light wrought-iron tee-bars. Blocks of asbestos are sometimes used for covering, instead of brick, the whole being covered over with plastic material of the same kind.

Where a single stack supplies several flues or registers, the connections between these and the warm-air chamber are made in the same manner as already described for furnace heating. When galvanized-iron casings are used, the heater is supported by hangers from the floor above. Fig. 59 shows the method of hanging a heater from a wooden floor. If the floor is of fireproof construction, the hangers may pass up through the brickwork, and the ends be provided with nuts and large washers or plates; or they may be clamped to the iron beams which carry the floor. Where brick casings are used, the heaters are supported upon pieces of pipe or light I-beams built into the walls.

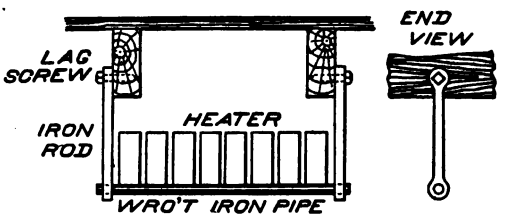


Fig. 59. Method of Hanging a Heater below a Wooden Floor.

The warm-air space above the heater should never be less than 8 inches, while 12 inches is preferable for heaters of large size. The cold-air space may be an inch or two less; but if there is plenty of room, it is good practice to make it the same as the space above.

Dampers. The general arrangement of a galvanized-iron casing and mixing damper is shown in Fig. 60. The cold-air duct is brought along the basement ceiling from the inlet window, and connects with the cold-air chamber beneath the heater. The entering air passes up between the sections, and rises through the register above, as shown by the arrows. When the mixing damper is in its lowest position, all air reaching the register must pass through the heater; but if the

damper is raised to the position shown, part of the air will pass by without going through the heater, and the mixture entering through the register will be at a lower temperature than before. By changing

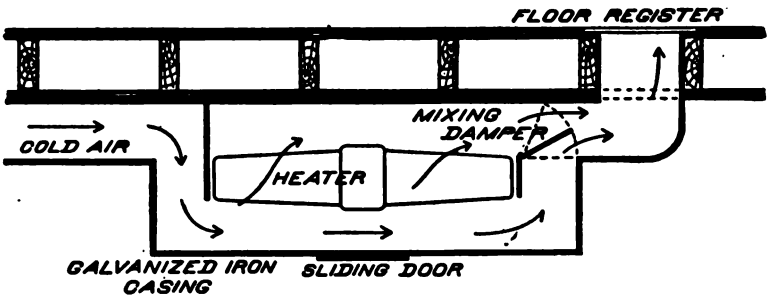


Fig. 60. General Arrangement of a Galvanized-Iron Casing and Mixing Damper. Damper between Heater and Register.

the position of the damper, the proportions of warm and cold air delivered to the room can be varied, thus regulating the temperature without diminishing to any great extent the quantity of air delivered

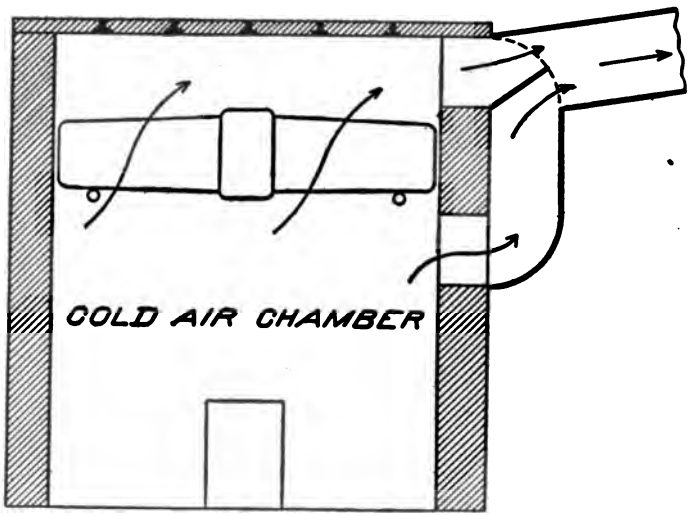


Fig. 61. Heater and Mixing Damper with Brick Casing. Damper between Heater and Register.

The objection to this form of damper is that there is a tendency for the air to enter the room before it is thoroughly mixed; that is, a stream of warm air will rise through one half of the register while

cold air enters through the other. This is especially true if the connection between the damper and register is short. Fig. 61 shows a similar heater and mixing damper, with brick casing. Cold air is admitted to the large chamber below the heater, and rises through the sections to the register as before. The action of the mixing damper is the same as already described. Several flues or registers may be connected with a stack of this form, each connection having, in addition to its mixing damper, an adjusting damper for regulating the flow of air to the different rooms.

Another way of proportioning the air-flow in cases of this kind is to divide the hot-air chamber above the heater into sections, by means of galvanized-iron partitions, giving to each room its proper share of heating surface. If the cold-air supply is made sufficiently large, this arrangement is preferable to using adjusting dampers as

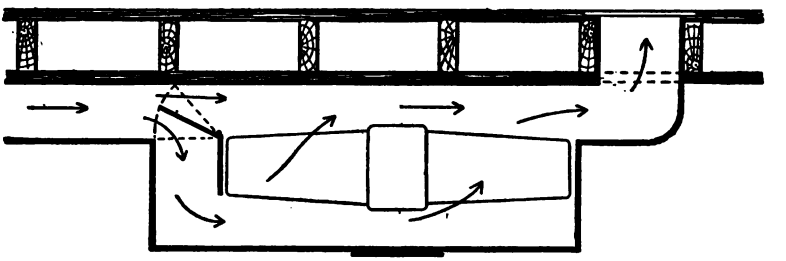


Fig. 62. Another Arrangement of Mixing Damper and Heater in Galvanized-Iron Casing. Heater between Damper and Register.

described above. The partitions should be carried down the full depth of the heater between the sections, to secure the best results.

The arrangement shown in Fig. 62 is somewhat different, and overcomes the objection noted in connection with Fig. 60, by substituting another. The mixing damper in this case is placed at the other end of the heater. When it is in its highest position, all of the air must pass through the heater before reaching the register; but when partially lowered, a part of the air passes over the heater, and the result is a mixture of cold and warm air, in proportions depending upon the position of the damper. As the layer of warm air in this case is below the cold air, it tends to rise through it, and a more thorough mixture is obtained than is possible with the damper shown in Fig. 60. One quite serious objection, however, to this form of damper, is illustrated in Fig. 63. When the damper is nearly

closed so that the greater part of the air enters above the heater, it has a tendency to fall between the sections, as shown by the arrows, and, becoming heated, rises again, so that it is impossible to deliver air to a room below a certain temperature. This peculiar action increases as the quantity of air admitted below the heater is diminished. When the inlet register is placed in the wall at some distance above the floor, as in schoolhouse work, a thorough mixture of air can be obtained by placing the heater so that the current of warm air will pass up the front of the flue and be discharged into the room through the lower part of the register. This is shown quite clearly in Fig. 64, where the current of warm air is represented by crooked arrows, and the cold air by straight arrows. The two currents pass up the flue separately; but as soon as they are discharged through the register the warm air tends to rise, and the cold air to fall, with the result of a more or less complete mixture, as shown.

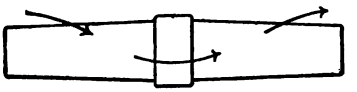


Fig. 63. Showing Difficulty of Regulating Temperature with Arrangement in Fig. 62.

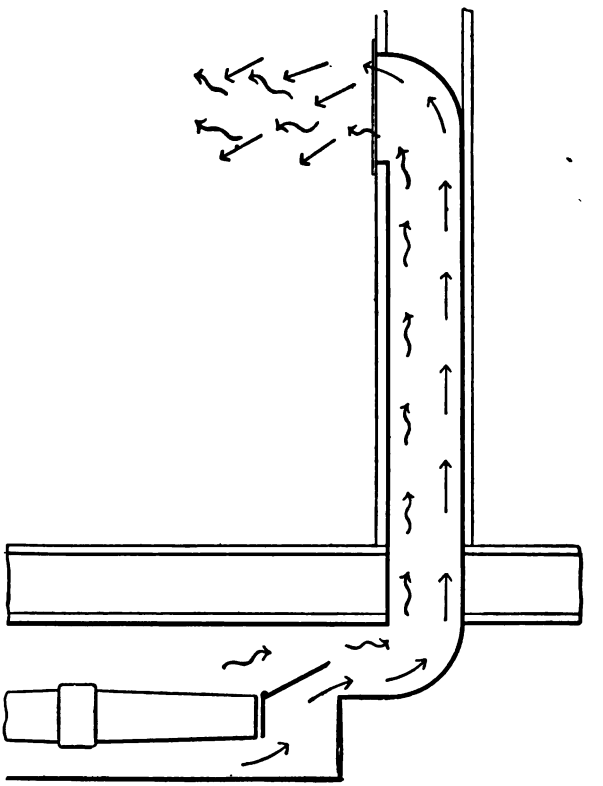


Fig. 64. Arrangement of Heater and Damper Causing Warm Air to Enter Room through Lower Part of Register, thus Securing Thorough Mixing

It is often desirable to warm a room at times when ventilation is not necessary, as in the case of living rooms during the night, or for quick warming in the morning. A register and damper for air rotation should be provided in this case. Fig. 65 shows an arrangement for this purpose. When the damper is in the position shown, air will be taken from the room above and be warmed over and over; but, by raising the damper, the supply will be taken from outside. Special care should be taken to make all mixing dampers tight against air-leakage, else their advantages will be lost. They should work easily and close tightly against flanges covered with felt. They may be operated from the rooms above by means of chains passing over

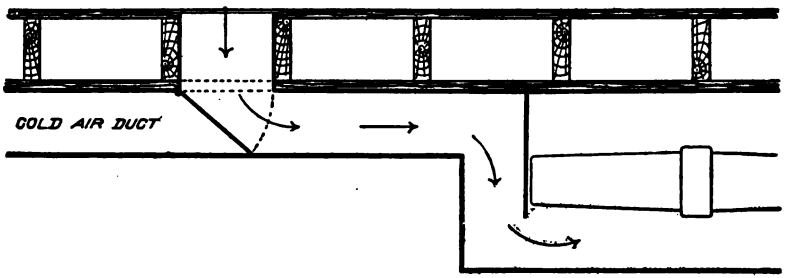


Fig. 65. Arrangement for Quick Heating without Ventilation. Damper Shuts off Fresh Air, and Air of Room Heated by Rotating Forth and Back through Register and Heater.

guide-pulleys; special attachments should be provided for holding in any desired position.

Warm-Air Flues. The required size of the warm-air flue between the heater and the register, depends first upon the difference in temperature between the air in the flue and that of the room, and second, upon the height of the flue. In dwelling-houses, where the conditions are practically constant, it is customary to allow 2 square inches area for each square foot of radiation when the room is on the first floor, and 1½ square inches for the second and third floors. In the case of hospitals, where a greater volume of air is required, these figures may be increased to 3 square inches for the first floor wards, and 2 square inches for those on the upper floors.

In schoolhouse work, it is more usual to calculate the size of flue from an assumed velocity of air-flow through it. This will vary greatly according to the outside temperature and the prevailing wind conditions. The following figures may be taken as average velocities

obtained in practice, and may be used as a basis for calculating the required flue areas for the different stories of a school building:

1st floor, 280 feet per minute.
2nd " , 340 " " "
3rd " , 400 " " "

These velocities will be increased somewhat in cold and windy weather and will be reduced when the atmosphere is mild and damp.

Having assumed these velocities, and knowing the number of cubic feet of air to be delivered to the room per minute, we have only to divide this quanity by the assumed velocity, to obtain the required flue area in square feet.

Example. A schoolroom on the second floor is to have an air-supply of 2,000 cubic feet per minute. What will be the required flue area?

ANS. $2000 \div 340 = 5.8 +$ sq. feet.

The velocities would be higher in the coldest weather, and dampers should be placed in the flues for throttling the air-supply when necessary.

Cold-Air Ducts. The cold-air ducts supplying heaters should be planned in a manner similar to that described for furnace heating. The air-inlet should be on the north or west side of the building; but this of course is not always possible. The method of having a large trunk line or duct with inlets on two or more sides of the building, should be carried out when possible. A cold-air room with large inlet windows, and ducts connecting with the heaters, makes a good arrangement for schoolhouse work. The inlet windows in this case should be provided with check-valves to prevent any outward flow of air. A detail of this arrangement is shown in Fig. 66.

This consists of a boxing around the window, extending from the floor to the ceiling. The front is sloped as shown, and is closed from the ceiling to a point below the bottom of the window. The remainder is open, and covered with a wire netting of about ½-inch mesh; to this are fastened flaps or checks of gossamer cloth about 6 inches in width. These are hemmed on both edges and a stout wire is run through the upper hem which is fastened to the netting by means of small copper or soft iron wire. The checks allow the air to flow inward but close when there is any tendency for the current to reverse.

The area of the cold-air duct for any heater should be about three-fourths the total area of the warm-air ducts leading from it.

If the duct is of any considerable length or contains sharp bends, it should be made the full size of all the warm-air ducts. Adjusting dampers should be placed in the supply duct to each separate stack. If a trunk with two inlets is used, each inlet should be of sufficient size to furnish the full amount of air required, and should be provided with cloth checks for preventing an outward flow of air, as already described. The inlet windows should be provided with some form of damper or slide, outside of which should be placed a wire grating, backed by a netting of about ⅜-inch mesh.

Vent Flues. In dwelling-houses, vent flues are often omitted, and the frequent opening of doors and leakage are depended upon to carry away the impure air. A well-designed system of warming should provide some means for discharge ventilation, especially for bathrooms and toilet-rooms, and also for living rooms where lights are burned in the evening. Fireplaces are usually provided in the more important rooms of a well-built house, and these are made to serve as vent flues. In rooms having no fireplaces, special flues of tin or galvanized iron may be carried up in the partitions in the same manner as the warm-air flues. These should be gathered together in the attic, and connected with a brick flue running up beside the boiler or range chimney.

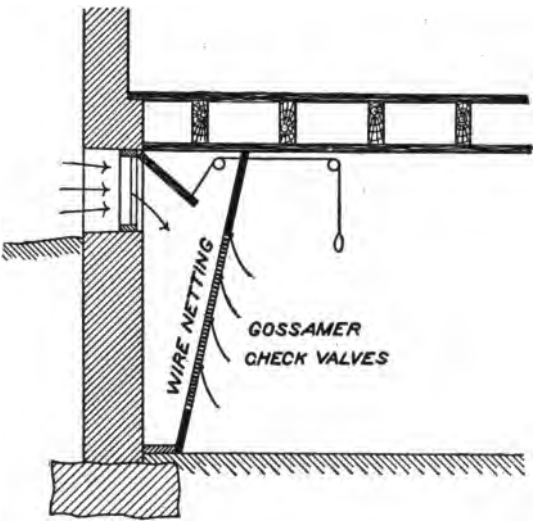


Fig. 66. Air-Inlet Provided with Check-Valves to Prevent Outward Flow of Air.

Very fair results may be obtained by simply letting the flues open into an unfinished attic, and depending upon leakage through the roof to carry away the foul air.

The sizes of flues may be made the reverse of the warm-air flues —that is, 1½ square inches area per square foot of indirect radiation for rooms on the first floor, and 2 square inches for those on the second. This is because the velocity of flow will depend upon the height of flue, and will therefore be greater from the first floor. The flow of air through the vents will be slow at best, unless some means is provided for warming the air in the flue to a temperature above that of the room with which it connects.

The method of carrying up the outboard discharge beside a warm chimney is usually sufficient in dwelling-houses; but when it is desired to move larger quantities of air, a loop of steam pipe should be run inside the flue. This should be connected for drainage and air-venting as shown in Fig. 67. When vents are carried through the roof independently, some form of protecting hood should be provided for keeping out the snow and rain. A simple form is shown in Fig. 68. Flues carried outboard in this way should always be extended well above the ridges of adjacent roofs to prevent down drafts in windy weather.

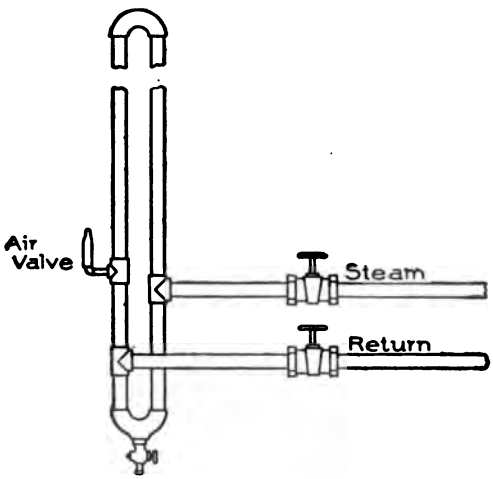


Fig. 67. Loop of Steam Pipe to be Run Inside Flue. Connected for Drainage and Air-Venting.

For schoolhouse work we may assume average velocities through the vent flues, as follows:

1st floor, 340 feet per minute.
2nd " , 280 " " "
3rd " , 220 " " "

Where flue sizes are based on these velocities, it is well to guard against down drafts by placing an aspirating coil in the flue. A single row of pipes across the flue as shown in Fig. 69, is usually sufficient for this purpose when the flues are large and straight;

otherwise, two rows should be provided. The slant height of the heater should be about twice the depth of the flue, so that the area between the pipes shall equal the free area of the flue.

Large vent flues of this kind should always be provided with dampers for closing at night, and for regulation during strong winds.

Sometimes it is desired to move a given quantity of air through a flue which is already in place. Table XXIV shows what velocities may be obtained through flues of different heights, for varying differences in temperature between the outside air and that in the flue.

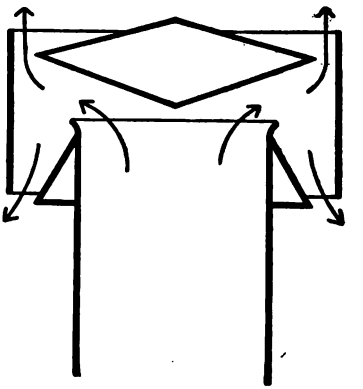


Fig. 68. Section Showing Simple Form of Protecting Hood for Vent Carried through Roof.

Example.—It is desired to discharge 1,300 cubic feet of air per minute through a flue having an area of 4 square feet and a height of 30 feet. If the efficiency of an aspirating coil is 400 B. T. U., how many square feet of surface will be required to move this amount of air when the temperature of the room is 70° and the outside temperature is 60°?

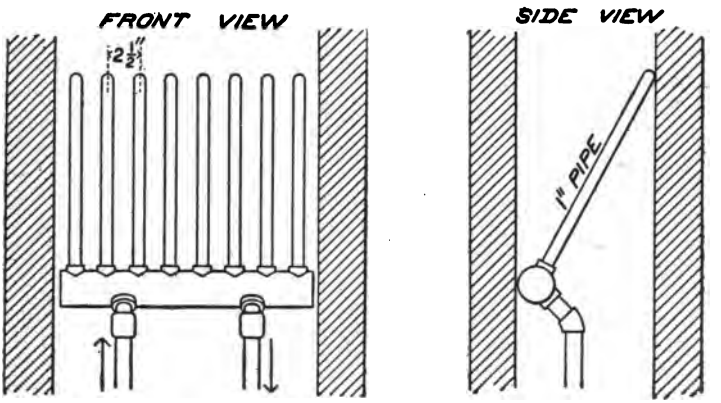


Fig. 69. Aspirating Coil Placed in Flue to Prevent Down Drafts.

1,300 ÷ 4 = 325 feet per minute = Velocity through the flue. Looking in Table XXIV, and following along the line opposite a 30-foot flue, we find that to obtain this velocity there must be a difference of 30 degrees between the air in the flue and the external air.

If the outside temperature is 60 degrees, then the air in the flue must be raised to 60 + 30 = 90 degrees. The air of the room being at 70 degrees, a rise of 20 degrees is necessary. So the problem resolves itself into the following: What amount of heating surface having an

TABLE XXIV

Air-Flow through Flues of Various Heights under Varying Conditions of Temperature

(Volumes given in cubic feet per square foot of sectional area of flue)

Height of Flue in Feet	Excess of Temperature of Air in Flue Above that of External Air					
	5°	10°	15°	20°	30°	50°
5	55	76	94	109	134	167
10	77	108	133	153	188	242
15	94	133	162	188	230	297
20	108	153	188	217	265	342
25	121	171	210	242	297	383
30	133	188	230	265	325	419
35	143	203	248	286	351	453
40	153	217	265	306	375	484
45	162	230	282	325	398	514
50	171	242	297	342	419	541
60	188	264	325	373	461	594

efficiency of 400 B. T. U. is necessary to raise 1,300 cubic feet of air per minute through 20 degrees?

1,300 cubic feet per minute = 1,300 × 60 = 78,000 per hour; and making use of our formula for "heat for ventilation," we have

$$\frac{78{,}000 \times 20}{55} = 28{,}363 \text{ B. T. U.};$$

and this divided by 400 = 71 square feet of heating surface required.

EXAMPLES FOR PRACTICE

1. A schoolroom on the third floor has 50 pupils, who are to be furnished with 30 cubic feet of air per minute each. What will be the required areas in square feet of the supply and vent flues?

ANS. Supply, 3.7 +. Vent, 6.8 +.

2. What size of heater will be required in a vent flue 40 feet high and with an area of 5 square feet, to enable it to discharge 1,530 cubic feet per minute, when the outside temperature is 60°? (Assume an efficiency of 400 B. T. U. for the heater.) ANS. 41.7 square feet.

Registers. Registers are made of cast iron and bronze, in a great variety of sizes and patterns. The almost universal finish for cast-iron registers is black "Japan;" but they are also finished in colors and electroplated with copper and nickel. Fig. 70 shows a section through a floor register, in which *A* represents the valves, which may be turned in a vertical or horizontal position, thus opening or closing the register; *B* is the iron border; *C*, the register box of tin or galvanized iron; and *D*, the warm-air pipe. Floor registers are usually set in cast-iron borders, one of which is shown in Fig. 71; while wall registers may be screwed directly to wooden borders or frames to correspond with the finish of the room. Wall registers should be provided with pull-cords for opening and closing from the floor; these are shown in Fig. 72. The plain lattice pattern shown in Fig. 73 is the best for schoolhouse work, as it has a comparatively free opening for air-flow and is pleasing and simple in design. More elaborate patterns are used for fine dwelling-house work. Registers with shut-off valves are used for air-inlets, while the plain register faces without the valves are placed in the vent openings. The vent flues are usually gathered together in the attic, and a single damper may be used to shut off the whole number at once. Flat or round wire gratings of open pattern are often used in place of

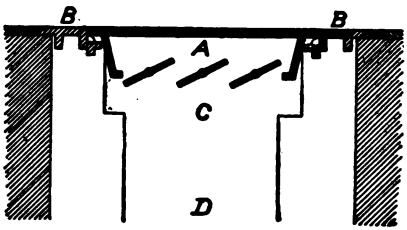


Fig. 70. Section through a Floor Register.

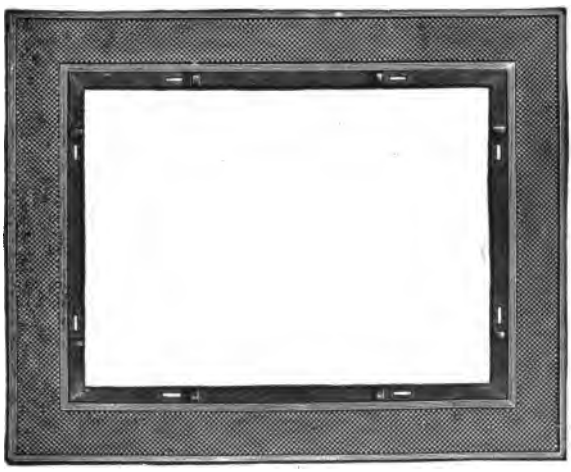


Fig. 71. Cast-Iron Border for a Floor Register.

register faces. The grill or solid part of a register face usually takes up about $\frac{1}{3}$ of the area; hence in computing the size, we must allow for this by multiplying the required "net area" by 1.5, to obtain the "total" or "over-all" area.

Example. Suppose we have a flue 10 inches in width and wish to use a register having a free area of 200 square inches. What will be the required height of the register?

$200 \times 1.5 = 300$ square inches, which is the total area required; then $300 \div 10 = 30$, which is the required height, and we should use a 10 by 30-inch register. When a register is spoken of as a 10 by

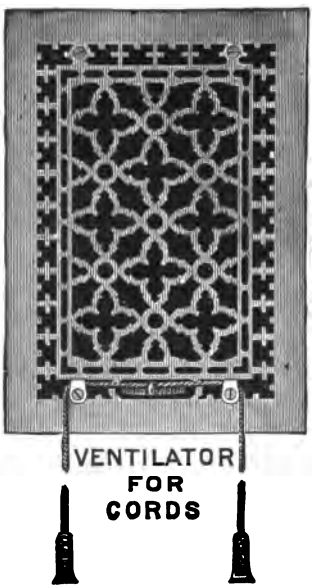


Fig. 72. Wall Register with Pull Cords for Opening and Closing.

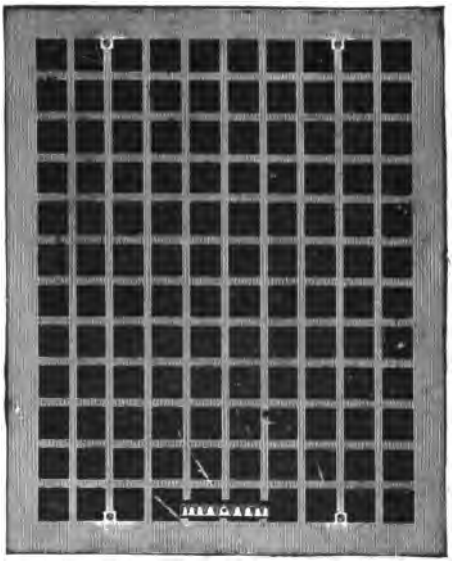


Fig. 73. Plain Lattice Pattern Register. Best for Schoolhouse Work.

30-inch or a 10 by 20-inch, etc., the dimensions of the latticed opening are meant, and not the outside dimensions of the whole register. The free opening should have the same area as the flue with which it connects. In designing new work, one should provide himself with a trade catalogue, and use only standard sizes, as special patterns and sizes are costly. Fig. 74 shows the method of placing gossamer check-valves back of the vent register faces to prevent down drafts, the same as described for fresh-air inlets.

Inlet registers in dwelling-house and similar work are placed either in the floor or in the baseboard; sometimes they are located under the windows, just above the baseboard. The object in view is to place them where the currents of air entering the room will not be objectionable to persons sitting near windows. A long, narrow floor-register placed close to the wall in front of a window, sends up a shallow current of warm air, which is not especially noticeable

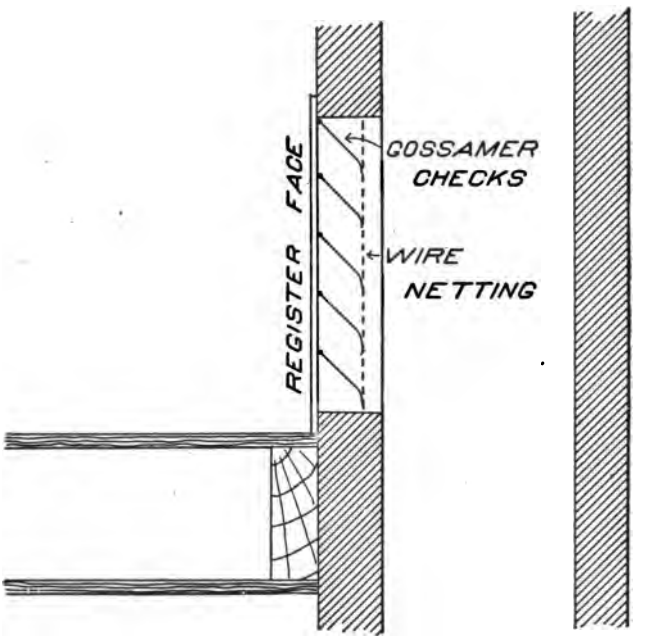


Fig. 74. Method of Placing Gossamer Check-Valves back of Vent Register Face to Prevent Down Drafts.

to one sitting near it. Inlet registers are preferably placed near outside walls; especially in large rooms. Vent registers should be placed in inside walls, near the floor.

Pipe Connections. The two-pipe system with dry or sealed returns is used in indirect heating. The conditions to be met are practically the same as in direct heating, the only difference being that the radiators are at the basement ceiling instead of on the floors above. The exact method of making the pipe connections will depend somewhat upon existing conditions; but the general method shown in Fig. 75 may be used as a guide, with modifications to suit

any special case. The ends of all supply mains should be dripped, and the horizontal returns should be sealed if possible.

Pipe Sizes. The tables already given for the proportioning of pipe sizes can be used for indirect systems. The following table has been computed for an efficiency of 640 B. T. U. per square foot of surface per hour, which corresponds to a condensation of $\frac{2}{3}$ of a pound of steam. This is twice that allowed for direct radiation in Table

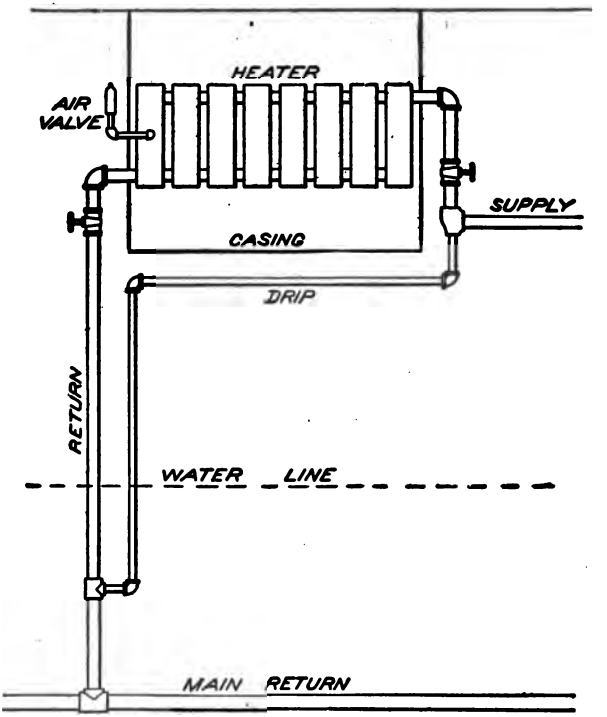


Fig. 75. General Method of Making Pipe and Radiator Connections, in Basement, in Indirect Heating.

XVII; so that we can consider 1 square foot of indirect surface as equal to 2 of direct in computing pipe sizes.

As the indirect heaters are placed in the basement, care must be taken that the bottom of the radiator does not come too near the water-line of the boiler, or the condensation will not flow back properly; this distance, under ordinary conditions, should not be less than 2 feet. If much less than this, the pipes should be made extra large, so that there may be little or no drop in pressure between the boiler

TABLE XXV

Indirect Radiating Surface Supplied by Pipes of Various Sizes

Size of Pipe	Square Feet of Indirect Radiation which will be Supplied with		
	¼ Pound Drop in 200 Feet	¼ Pound Drop in 100 Feet	½ Pound Drop in 100 Feet
1 in.	28	40	57
1¼ "	51	72	105
1½ "	67	95	170
2 "	185	262	375
2½ "	335	475	675
3 "	540	775	1,105
3½ "	812	1,160	1,645
4 "	1,140	1,625	2,310
5 "	2,030	2,900	4,110
6 "	3,260	4,660	6,600
7 "	4,830	6,900	9,810
8 "	6,800	9,720	13,860

and the heater. A drop in pressure of 1 pound would raise the water-line at the heater 2.4 feet.

Fig. 76. General Form of Direct-Indirect Radiator.

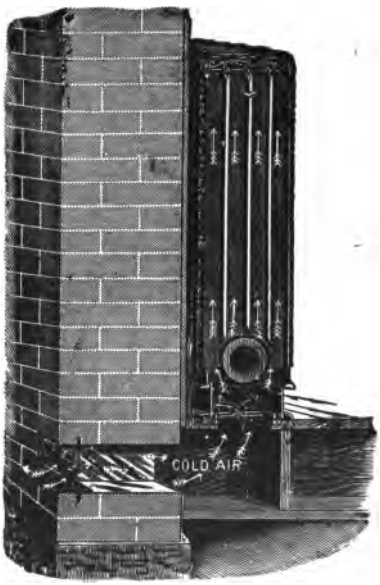


Fig. 77. Section through Radiator Shown in Fig. 76.

Direct-Indirect Radiators. A direct-indirect radiator is similar in form to a direct radiator, and is placed in a room in the same

manner. Fig. 76 shows the general form of this type of radiator; and Fig. 77 shows a section through the same. The shape of the sections is such, that when in place, small flues are formed between them. Air is admitted through an opening in the outside wall; and, in passing upward through these flues, becomes heated before entering the room. A switch-damper is placed in the duct at the base of the radiator, so that the air may be taken from the room itself instead of from out of doors, if so desired. This is shown more particularly in Fig. 76.

Fig. 78 shows the wall box provided with louvre slats and netting, through which the air is drawn. A damper door is placed at either end of the radiator base; and, if desired, when the cold-air supply is shut off by means of the register in the air-duct, the radiator can be converted into the ordinary type by opening both damper doors, thus taking the air from the room instead of from the outside. It is customary to increase the size of a direct-indirect radiator 30 per cent above that called for in the case of direct heating.

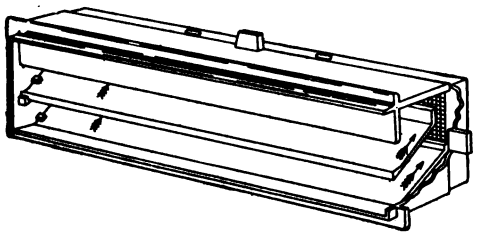


Fig. 78. Wall Box with Louvre Slats and Netting, Direct-Indirect System.

CARE AND MANAGEMENT OF STEAM-HEATING BOILERS

Special directions are usually supplied by the maker for each kind of boiler, or for those which are to be managed in any peculiar way. The following general directions apply to all makes, and may be used regardless of the type of boiler employed:

Before starting the fire, see that the boiler contains sufficient water. The water-line should be at about the center of the gauge-glass.

The smoke-pipe and chimney flue should be clean, and the draft good.

Build the fire in the usual way, using a quality of coal which is best adapted to the heater. In operating the fire, keep the firepot

full of coal, and shake down and remove all ashes and cinders as often as the state of the fire requires it.

Hot ashes or cinders must not be allowed to remain in the ashpit under the grate-bars, but must be removed at regular intervals to prevent burning out the grate.

To control the fire, see that the damper regulator is properly attached to the draft doors and the damper; then regulate the draft by weighting the automatic lever as may be required to obtain the necessary steam pressure for warming. Should the water in the boiler escape by means of a broken gauge-glass, or from any other cause, the fire should be dumped, and the boiler allowed to cool before adding cold water.

An empty boiler should never be filled when hot. If the water gets low at any time, but still shows in the gauge-glass, more water should be added by the means provided for this purpose.

The safety-valve should be lifted occasionally to see that it is in working order.

If the boiler is used in connection with a gravity system, it should be cleaned each year by filling with pure water and emptying through the blow-off. If it should become foul or dirty, it can be thoroughly cleansed by adding a few pounds of caustic soda, and allowing it to stand for a day, and then emptying and thoroughly rinsing.

During the summer months, it is recommended that the water be drawn off from the system, and that air-valves and safety-valves be opened to permit the heater to dry out and to remain so. Good results, however, are obtained by filling the heater full of water, driving off the air by boiling slowly, and allowing it to remain in this condition until needed in the fall. The water should then be drawn off and fresh water added.

The heating surface of the boiler should be kept clean and free from ashes and soot by means of a brush made especially for this purpose.

Should any of the rooms fail to heat, examine the steam valves in the radiators. If a two-pipe system, both valves at each radiator must be opened or closed at the same time, as required. See that the air-valves are in working condition.

If the building is to be unoccupied in cold weather, draw all the water out of the system by opening the blow-off pipe at the boiler and all steam valves and air-valves at the radiators.

HOT-WATER HEATERS

Types. Hot-water heaters differ from steam boilers principally in the omission of the reservoir or space for steam above the heating surface. The steam boiler might answer as a heater for hot water; but the large capacity left for the steam would tend to make its operation slow and rather unsatisfactory, although the same type of boiler is sometimes used for both steam and hot water. The passages in a hot-water heater need not extend so directly from bottom to top as in a steam boiler, since the problem of providing for the free liberation of the steam bubbles does not have to be considered. In general, the heat from the furnace should strike the surfaces in such a manner as to increase the natural circulation; this may be accomplished to a certain extent by arranging the heating surface so that a large proportion of the direct heat will be absorbed near the top of the heater. Practically the boilers for low-pressure steam and for hot water differ from each other very little as to the character of the heating surface, so that the methods already given for computing the size of grate surface, horse-power, etc., under the head of "Steam

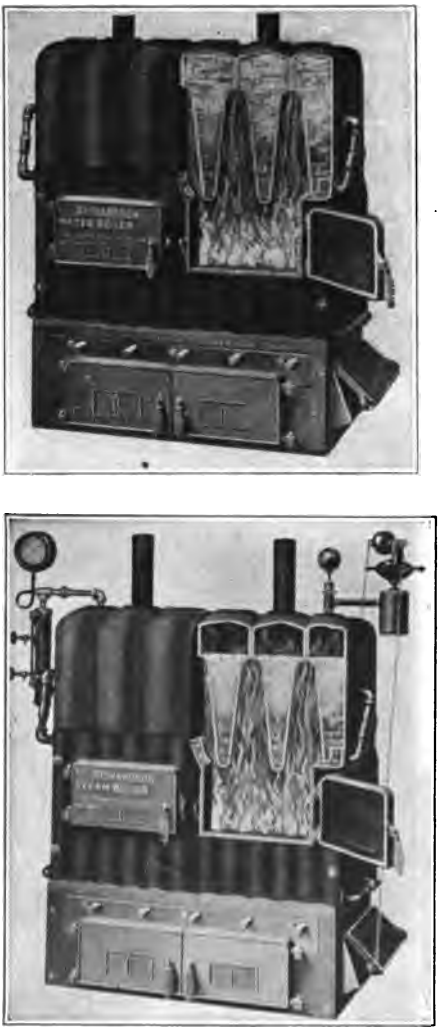


Fig. 79. Top—Richardson Sectional Hot-Water Heater. Bottom—Same Heater Equipped as Steam Boiler.

Courtesy of Richardson and Boynton, New York City.

Boilers," can be used with satisfactory results in the case of hot-water heaters.

It is sometimes stated that, owing to the greater difference in temperature between the furnace gases and the water in a hot-water heater, as compared with steam, the heating surface will be more efficient and a smaller heater can be used. While this is true to a certain extent, different authorities agree that this advantage is so small that no account should be taken of it, and the general proportions of the heater should be calculated in the same manner as for steam. Fig. 79 shows a form of heater made up of slabs or sections similar to the sectional steam boiler shown in Part I. The size can be increased in a similar manner, by adding more sections. In this case, however, the boiler is increased in width instead of in length. This has an advantage in the larger sizes, as a second fire door can be added, and all parts of the grate can be reached as well in the large sizes as in the small.

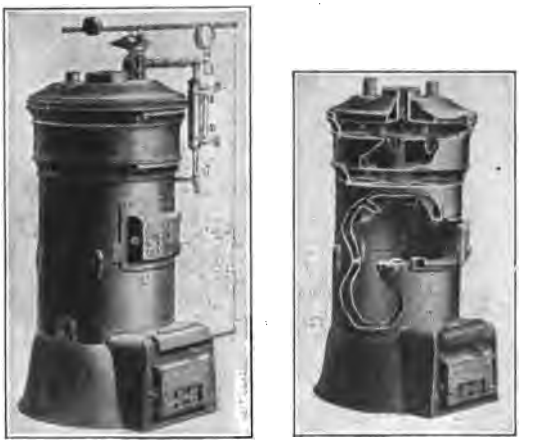


Fig. 80. "Standard" Boiler, with Sections Superposed.
Courtesy of Giblin and Company, Utica, New York.

Fig. 80 shows a boiler consisting of fire pot, feed section, intermediate reservoir, and a cored top. This boiler is circular in form and well adapted to dwelling-houses and similar work. The cut at the left shows the boiler equipped for steam by the attachment of gages and water glass. The cut at the right shows the proper equipment for the hot-water system, the heater being shown in part sections to give an idea of the construction.

Fig. 81 shows another type of sectional cast-iron heater. A deep fire chamber with corrugated sides makes this furnace a quick heater and keeps the fire a long time without attention. The space between the outer and inner corrugated shells surrounding the furnace, as shown by the part section in Fig. 81, is filled with water,

as is also the case with the cross-pipes directly over the fire and the drum at the top.

The ordinary horizontal and vertical tubular boilers, with various modifications, are used to a considerable extent for hot-water heating, and are well adapted to this class of work, especially in the case of large buildings.

Automatic regulators are often used for the purpose of maintaining a constant temperature of the water. They are constructed in different ways—some depend upon the expansion of a metal pipe or rod at different temperatures, and others upon the vaporization and consequent pressure of certain volatile liquids. These means are usually employed to open small valves which admit water pressure under rubber diaphragms; and these in turn are connected by means of chains with the draft doors of the furnace, and so regulate the draft as required to maintain an even temperature of the water in the heater. Fig. 82 shows one of the first kind. *A* is a metal rod placed in the flow pipe from the heater, and is so connected with the valve *B* that when the water reaches a certain temperature the expansion of the rod opens the valve and admits water from the street pressure through the pipes *C* and *D* into the chamber *E*. The bottom of *E* consists of a rubber diaphragm, which is forced down by the water pressure and carries with it the lever which operates the dampers as shown, and checks the fire. When the temperature of the water drops, the rod contracts and valve *B* closes, shutting off the pressure from the chamber *E*. A spring is provided to throw the lever back to its original position,

Fig. 81. Cast-Iron Heater Made in Sections. Water Fills Space Between Outer and Inner Shells and Drum at Top.
Courtesy of Richardson and Boynton Company, New York City.

and the water above the diaphragm is forced out through the petcock *G*, which is kept slightly open all the time.

DIRECT HOT-WATER HEATING

A hot-water system is similar in construction and operation to one designed for steam, except that *hot water* flows through the pipes and radiators instead.

The circulation through the pipes is produced solely by the difference in weight of the water in the supply and return, due to the difference in temperature. When water is heated it expands, and thus a given volume becomes lighter and tends to rise, and the cooler water flows in to take its place; if the application of heat is kept up, the circulation thus produced is continuous. The velocity of flow depends upon the difference in temperature between the supply and return, and the height of the radiator above the boiler. The horizontal distance of the radiator from the boiler is also an important factor affecting the velocity of flow.

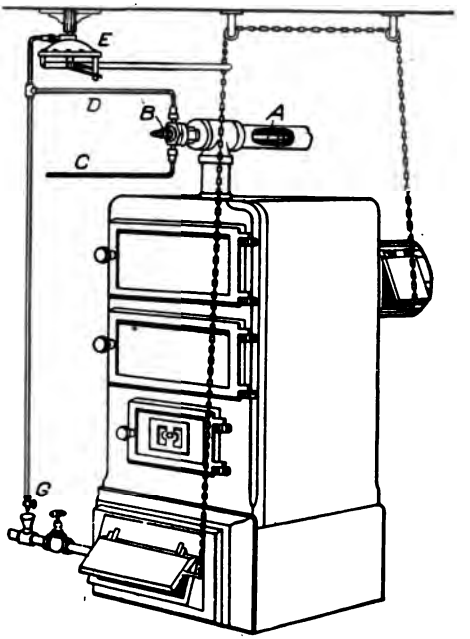


Fig. 82. Hot-Water Heater with Automatic Regulator Operated through Expansion and Contraction of Metal Rod in Flow Pipe.

This action is best shown by means of a diagram, as in Fig. 83. If a glass tube of the form shown in the figure is filled with water and held in a vertical position, no movement of the water will be noticed, because the two columns *A* and *B* are of the same weight, and therefore in equilibrium. Now, if a lamp flame be held near the tube *A*, the small bubbles of steam which are formed will show the water to be in motion, with a current flowing in the direction indicated by the arrows. The reason for this is, that, as the water in *A* is heated,

it expands and becomes lighter for a given volume, and is forced upward by the heavier water in *B* falling to the bottom of the tube. The heated water flows from *A* through the connecting tube at the top, into *B*, where it takes the place of the cooler water which is settling to the bottom. If, now, the lamp be replaced by a furnace, and the columns *A* and *B* be connected at the top by inserting a radiator, the illustration will assume the practical form as utilized in hot-water heating (see Fig. 84).

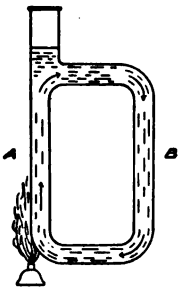


Fig. 83. Illustrating How the Heating of Water Causes Circulation.

The heat given off by the radiator always insures a difference in temperature between the columns of water in the supply and return pipes, so that as long as heat is supplied by the furnace the flow of water will continue. The greater the difference in temperature of the water in the two pipes, the greater the difference in weight, and consequently the faster the flow. The greater the height of the radiator above the heater, the more rapid will be the circulation, because the total difference in weight between the water in the supply and return risers will vary directly with their height. From the above it is evident that the rapidity of flow depends chiefly upon the *temperature* difference between the supply and return, and upon the *height of the radiator* above the heater. Another factor which must be considered in long runs of horizontal pipe is the *frictional resistance.*

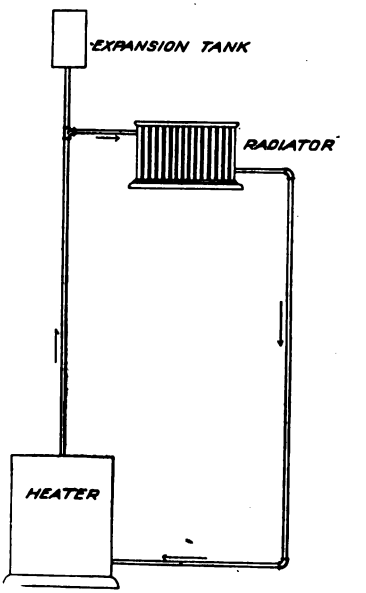


Fig. 84. Illustrating Simple Circulation in a Heating System.

Systems of Circulation. There are two distinct systems of circulation employed—one depending on the difference in temperature of the water in the supply and return pipes, called *gravity circulation*;

and another where a pump is used to force the water through the mains, called *forced circulation.* The former is used for dwellings and other buildings of ordinary size, and the latter for large buildings, and especially where there are long horizontal runs of pipe.

For gravity circulation some form of sectional cast-iron boiler is commonly used, although wrought-iron tubular boilers may be employed if desired. In the case of forced circulation, a heater designed to warm the water by means of live or exhaust steam is often used. A centrifugal or rotary pump is best adapted to this purpose, and may be driven by an electric motor or a steam engine, as most convenient.

Types of Radiating Surface. Cast-iron radiators and circulation coils are used for hot water as well as for steam. Hot-water radiators differ from steam radiators principally in having a horizontal passage at the top as well as at the bottom. This construction is necessary in order to draw off the air which gathers at the top of each loop or section. Otherwise they are the same as steam radiators, and are well adapted for the circulation of steam, and in some respects are superior to the ordinary pattern of steam radiator.

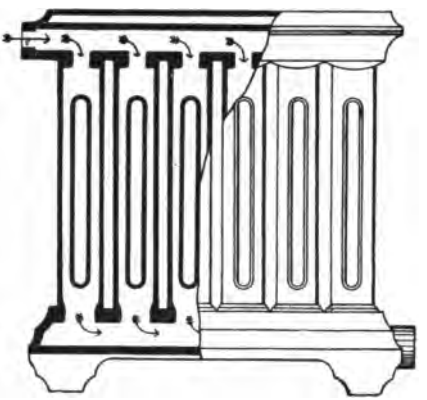


Fig. 85. Showing Construction of Radiator for Hot Water or Steam. Note Horizontal Passage along Top.

The form shown in Fig. 85 is made with an opening at the top for the entrance of water, and at the bottom for its discharge, thus insuring a supply of hot water at the top and of colder water at the bottom.

Some hot-water radiators are made with a cross-partition so arranged that all water entering passes at once to the top, from which it may take any passage toward the outlet. Fig. 86 is the more common form of radiator, and is made with continuous passages at top and bottom, the hot water being supplied at one side and drawn off at the other. The action of gravity is depended upon for making the hot and lighter water pass to the top, and the colder water sink

to the bottom and flow off through the return. Hot-water radiators are usually tapped and plugged so that the pipe connections can be made either at the top or at the bottom. This is shown in Fig. 87.

Wall radiators are adapted to hot-water as well as steam heating.

Efficiency of Radiators. The efficiency of a hot-water radiator depends entirely upon the temperature at which the water is circulated. The best practical results are obtained with the water leaving the boiler at a maximum temperature of about 180 degrees in zero weather and returning at about 160 degrees; this gives an average

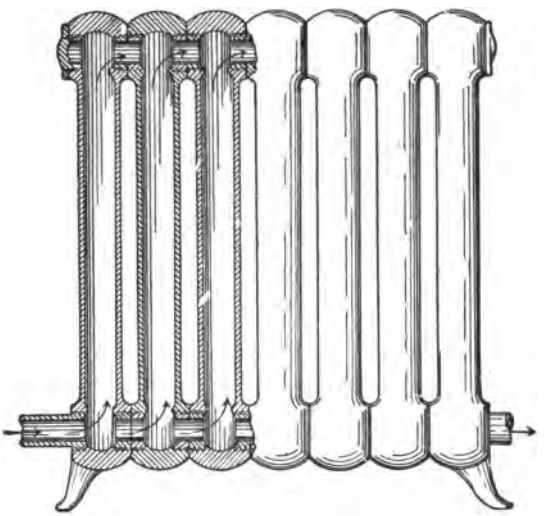


Fig. 86. Common Form of Hot-Water Radiator. Circulation Produced Wholly through Action of Gravity, Hot Water Rising to Top.

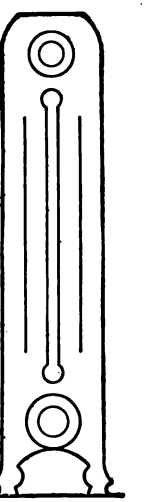


Fig. 87. End Elevation of Radiator Showing Taps at Top and Bottom for Pipe Connections.

temperature of 170 degrees in the radiators. Variations may be made, however, to suit the existing conditions of outside temperature. We have seen that an average cast-iron radiator gives off about 1.7 B.T.U. per hour per square foot of surface per degree difference in temperature between the radiator and the surrounding air, when working under ordinary conditions; and this holds true whether it is filled with steam or water.

If we assume an average temperature of 170 degrees for the water, then the difference in temperature between the radiator and the air will be $170-70=100$ degrees; and this multiplied by $1.7=$

170, which may be taken as the efficiency of a hot-water radiator under the above average conditions.

This calls for a water radiator about 1.5 times as large as a steam radiator to heat a given room under the same conditions. This is common practice although some engineers multiply by the factor 1.6, which allows for a lower temperature of the water. Water leaving the boiler at 170 degrees should return at about 150; the drop in temperature should not ordinarily exceed 20 degrees.

Systems of Piping. A system of hot-water heating should produce a perfect circulation of water from the heater to the radiating

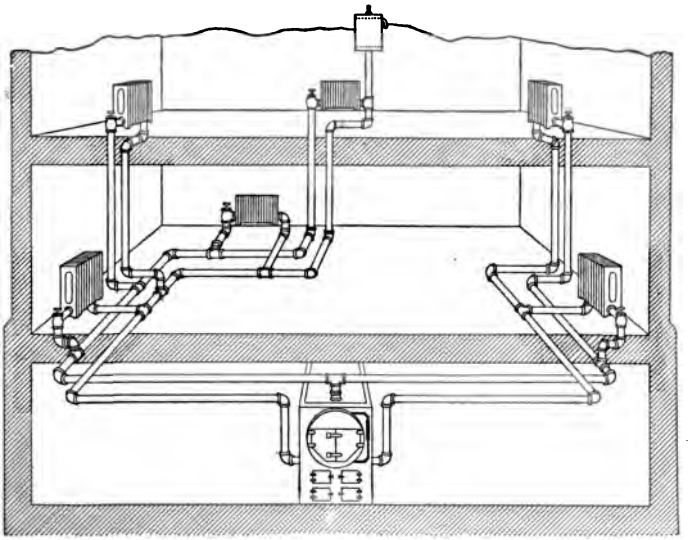


Fig. 88. System of Piping Usually Employed for Hot-Water Heating.

surface, and thence back to the heater through the returns. The system of piping usually employed for hot-water heating is shown in Fig. 88. In this arrangement the main and branches have an inclination upward from the heater; the returns are parallel to the mains, and have an inclination downward toward the heater, connecting with it at the lowest point. The flow pipes or risers are taken from the tops of the mains, and may supply one or more radiators as required. The return risers or drops are connected with the return mains in a similar manner. In this system great care must be taken to produce a nearly equal resistance to flow in all of the branches, so that each radiator may receive its full supply of water. It will always

be found that the principal current of heated water will take the path of least resistance, and that a small obstruction or irregularity in the piping is sufficient to interfere greatly with the amount of heat received in the different parts of the same system.

Some engineers prefer to carry a single supply main around the building, of sufficient size to supply all the radiators, bringing back a single return of the same size. Practice has shown that in general it is not well to use pipes over 8 or 10 inches in diameter; if larger pipes are required, it is better to run two or more branches.

The boiler, if possible, should be centrally located, and branches carried to different parts of the building. This insures a more even circulation than if all the radiators are supplied from a single long main, in which case the circulation is liable to be sluggish at the farther end.

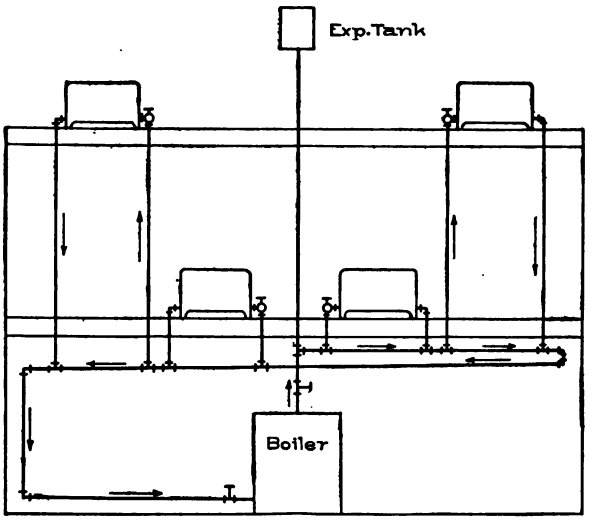


Fig. 89. System of Hot-Water Piping Especially Adapted to Apartment Buildings where Each Flat Has a Separate Heater.

The arrangement shown in Fig. 89 is similar to the circuit system for steam, except that the radiators have two connections instead of one. This method is especially adapted to apartment houses, where each flat has its separate heater, as it eliminates a separate return main, and thus reduces, by practically one-half, the amount of piping in the basement. The supply risers are taken from the top of the main; while the returns should connect into the side a short distance beyond, and in a direction *away* from the boiler. When this system is used, it is necessary to enlarge the radiators slightly as the distance from the boiler increases.

In flats of eight or ten rooms, the size of the last radiator may be increased from 10 to 15 per cent. and the intermediate ones propor-

tionally, at the same time keeping the main of a large and uniform size for the entire circuit.

Overhead Distribution. This system of piping is shown in Fig. 90. A single riser is carried directly to the expansion tank, from which branches are taken to supply the various drops to which the radiators are connected. An important advantage in connection with this system is that the air rises at once to the expansion tank, and escapes through the vent, so that air-valves are not required on the radiators.

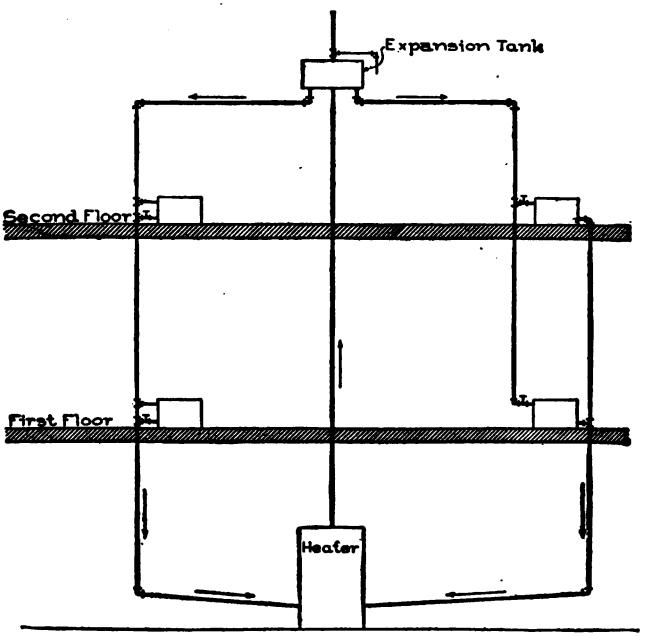


Fig. 90. "Overhead" Distribution System of Hot-Water Piping.

At the same time, it has the disadvantage that the water in the tank is under less pressure than in the heater; hence it will boil at a lower temperature. No trouble will be experienced from this, however, unless the temperature of the water is raised above 212 degrees.

Expansion Tank. Every system for hot-water heating should be connected with an expansion tank placed at a point somewhat above the highest radiator. The tank must in every case be connected to a line of piping which cannot by any possible means be shut off from the boiler. When water is heated, it expands a certain amount,

depending upon the temperature to which it is raised; and a tank or reservoir should always be provided to care for this increase in volume.

Expansion tanks are usually made of heavy galvanized iron of one of the forms shown in Figs. 91 and 92, the latter form being used where the headroom is limited. The connection from the heating system enters the bottom of the tank, and an open vent pipe is taken from the top. An overflow connected with a sink or drain-pipe should be provided. Connections should be made with the water supply both at the boiler and at the expansion tank, the former to be used when first filling the system, as by this means all air is driven from the bottom upward and is discharged through the vent at the expansion tank. Water that is added afterward may be supplied directly to the expansion tank, where the water-line can be noted in the gauge-glass. A ball-cock is sometimes arranged to keep the water-line in the tank at a constant level.

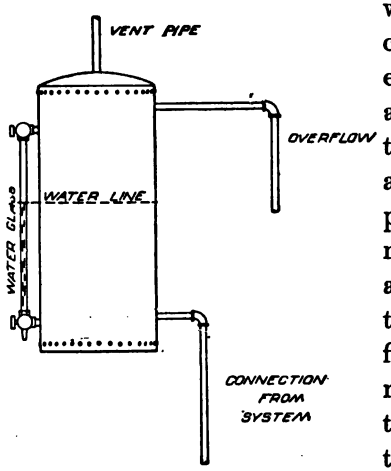


Fig. 91. A Common Form of Galvanized-Iron Expansion Tank.

An *altitude gauge* is often placed in the basement with the colored hand or pointer set to indicate the normal water-line in the expansion tank. When the movable hand falls below the fixed one, more water may be added, as required, through the supply pipe at the boiler. When the tank is placed in an attic or roof space where there is danger of freezing, the expansion pipe may be connected into the side of the

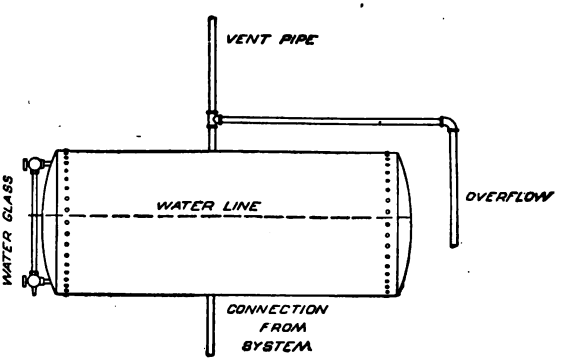


Fig. 92. Form of Expansion Tank Used where Headroom is Limited.

tank, 6 or 8 inches from the bottom, and a circulation pipe taken from the lower part and connected with the return from an upper-floor radiator. This produces a slow circulation through the tank, and keeps the water warm.

The size of the expansion tank depends upon the volume of water contained in the system, and on the temperature to which it is heated. The following rule for computing the capacity of the tank may be used with satisfactory results:

Square feet of radiation, *divided by* 40, equals required capacity of tank in gallons.

Air-Venting. One very important point to be kept in mind in the design of a hot-water system, is the removal of air from the pipes and radiators. When the water in the boiler is heated, the air it contains forms into small bubbles which rise to the highest points of the system.

In the arrangement shown in Fig. 88, the main and branches grade upward from the boiler, so that the air finds its way into the radiators, from which it may be drawn off by means of the air-valves.

A better plan is that shown in Fig. 89. In this case the expansion pipe is taken directly off the top of the main over the boiler, so that the larger part of the air rises directly to the expansion tank and escapes through the vent pipe. The same action takes place in the overhead system shown in Fig. 90, where the top of the main riser is connected with the tank. Every high point in the system and every radiator, except in the downward system with top supply connection, should be provided with an air-valve.

Pipe Connections. There are various methods of connecting the radiators with the mains and risers. Fig. 93 shows a radiator connected with the horizontal flow and return mains, which are located below the floor. The manner of connecting with a vertical riser and return drop is shown in Fig. 94. As the water tends to flow to the highest point, the radiators on the lower floors should be favored by making the connection at the top of the riser and taking the pipe for the upper floors from the side as shown. Fig. 95 illustrates the manner of connecting with a radiator on an upper floor where the supply is connected at the top of the radiator.

The connections shown in Figs. 96 and 97 are used with the overhead system shown in Fig. 90.

Where the connection is of the form shown at the left in Fig. 90, the cooler water from the radiators is discharged into the supply pipe again, so that the water furnished to the radiators on the lower floors is at a lower temperature, and the amount of heating surface must be correspondingly increased to make up for this loss, as already described for the circuit system.

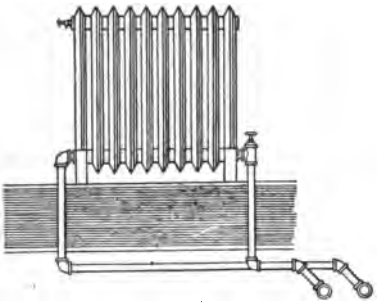


Fig. 93. Radiator Connected with Horizontal Flow and Return Mains Located below Floor.

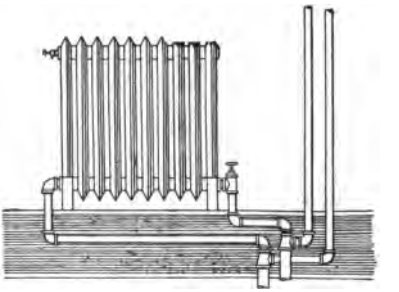


Fig. 94. Radiator Connected to Vertical Riser and Return Drop.

For example, if in the case of Fig. 90 we assume the water to leave at 180 degrees and return at 160, we shall have a drop in temperature of 10 degrees on each floor; that is, the water will enter the radiator on the second floor at 180 degrees and leave it at 170, and will enter the radiator on the first floor at 170 and leave it at 160.

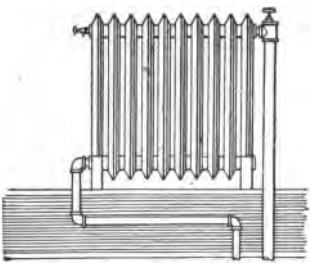


Fig. 95. Upper-Floor Radiator with Supply Connected at Top.

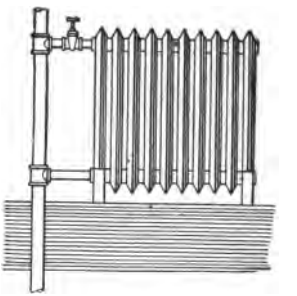


Fig. 96. Radiator Connections, Overhead Distribution System.

The average temperatures will be 175 and 165, respectively. The efficiency in the first case will be $175 - 70 = 105$; and $105 \times 1.5 = 157$. In the second case, $165 - 70 = 95$; and $95 \times 1.5 = 142$; so that the radiator on the first floor will have to be larger than that on the second floor in the ratio of 157 to 142, in order to do the same work.

This is approximately an increase of 10 per cent for each story downward to offset the cooling effect; but in practice the supply drops are made of such size that only a part of the water is by-passed through the radiators. For this reason an increase of 5 per cent for each story downward is probably sufficient in ordinary cases.

Where the radiators discharge into a separate return as in the case of Fig. 88, or those at the right in Fig. 90, we may assume the temperature of the water to be the same on all floors, and give the radiators an equal efficiency.

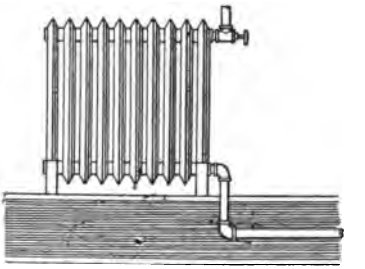


Fig. 97. Another Form of Radiator Connection, Overhead Distribution System.

In a dwelling-house of two stories, no difference would be made in the sizes of radiators on the two floors; but in the case of a tall office building, corrections would necessarily be made as above described.

Where circulation coils are used, they should be of a form which will tend to produce a flow of water through them. Figs. 98, 99, and 100 show different ways of making up and connecting these coils. In Figs. 98 and 100, supply pipes may be either drops or risers; and

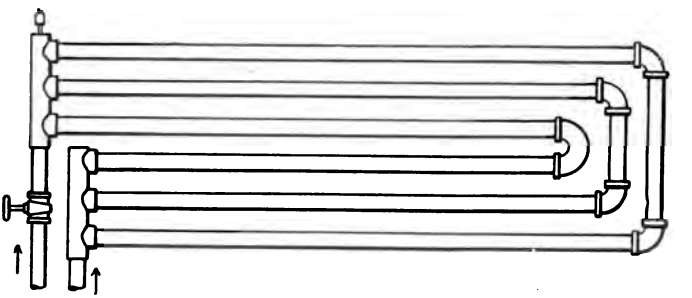


Fig. 98. Circulation Coil, One Method of Construction. Supply Pipes may be Either Drops or Risers.

in the former case the return in Fig. 100 may be carried back, if desired, into the supply drop, as shown by the dotted lines.

Combination Systems. Sometimes the boiler and piping are arranged for either steam or hot water, since the demand for a higher or lower temperature of the radiators might change.

The object of this arrangement is to secure the advantages of a hot-water system for moderate temperatures, and of steam heating for extremely cold weather.

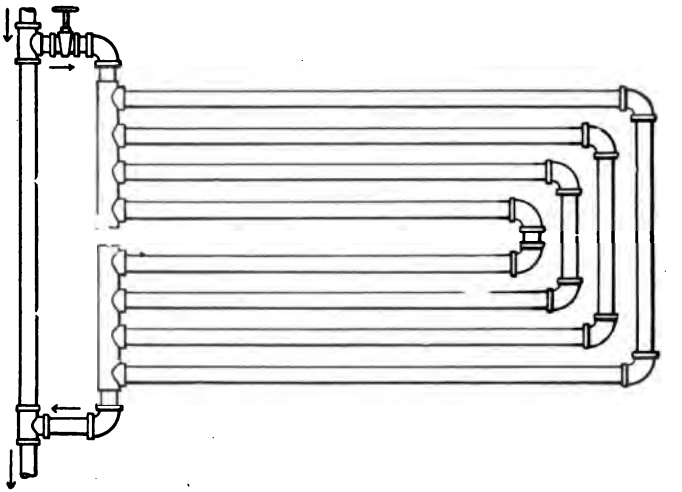


Fig. 99. Another Method of Building Up a Circulation Coil.

As less radiating surface is required for steam heating, there is an advantage due to the reduction in first cost. This is of considerable importance, as a heating system must be designed of such dimensions as to be capable of warming a building in the coldest weather;

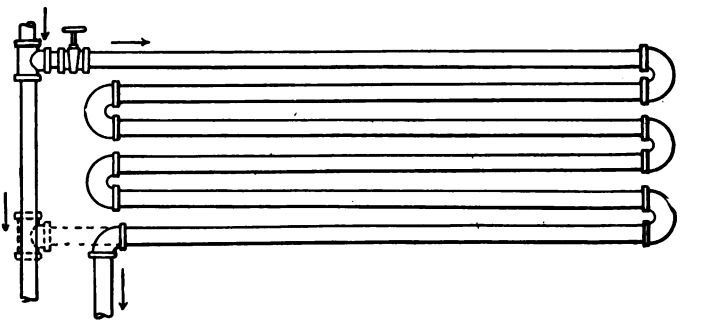


Fig. 100. Circulation Coil with Either Drop or Riser Supply. In former case, return may be carried into Supply Drop as shown by Dotted Lines.

and this involves the expenditure of a considerable amount for radiating surfaces, which are needed only at rare intervals. A combination system of hot-water and steam heating requires, *first*, a heater or boiler

which will answer for either purpose; *second,* a system of piping which will permit the circulation of either steam or hot water; and *third,* the use of radiators which are adapted to both kinds of heating. These requirements will be met by using a steam boiler provided with all the fittings required for steam heating, but so arranged that the damper regulator may be closed by means of valves when the system is to be used for hot-water heating. The addition of an expansion tank is required, which must be so arranged that it can be shut off when the system is used for steam heating. The system of piping shown in Fig. 88 is best adapted for a combination system, although an overhead distribution as shown in Fig. 90 may be used by shutting off the vent and overflow pipes, and placing air-valves on the radiators.

While this system has many advantages in the way of cost over the complete hot-water system, the labor of changing from steam to hot water will in some cases be troublesome; and should the connections to the expansion tank not be opened, serious results would follow.

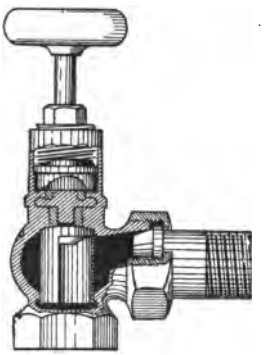


Fig. 101. Radiator Valve for Hot-Water Work.

Valves and Fittings. Gate-valves should always be used in connection with hot-water piping, although angle-valves may be used at the radiators. There are several patterns of radiator valves made especially for hot-water work; their chief advantage lies in a device for quick closing, usually a quarter-turn or half-turn being sufficient to open or close the valve. Two different designs are shown in Figs. 101 and 102.

It is customary to place a valve in only one connection, as that is sufficient to stop the flow of water through the radiator; a fitting known as a *union elbow* is often employed in place of the second valve. (See Fig. 103.)

Air-Valves. The ordinary pet-cock air-valve is the most reliable for hot-water radiators, although there are several forms of automatic valves which are claimed to give satisfaction. One of these is shown in Fig. 104. This is similar in construction to a steam trap. As air collects in the chamber, and the water-line is lowered, the float drops, and in so doing opens a small valve at the top of the

chamber, which allows the air to escape. As the water flows in to take its place, the float is forced upward and the valve is closed.

All radiators which are supplied by risers from below, should be provided with air-valves placed in the top of the last section at the return end. If they are supplied by drops from an overhead system, the air will be discharged at the expansion tank, and air-valves will not be necessary at the radiators.

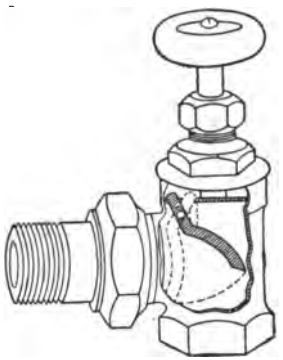


Fig. 102. Another Type of Hot-Water Radiator Valve.

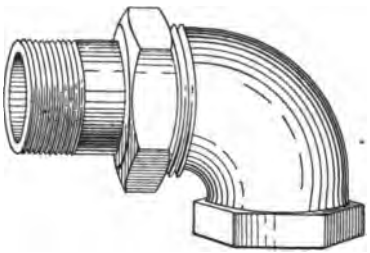


Fig. 103. Union Elbow.

Fittings. All fittings, such as elbows, tees, etc., should be of the *long-turn* pattern. If the common form is used, they should be a size larger than the pipe, bushed down to the proper size. The long-turn fittings, however, are preferable, and give a much better appearance. Connections between the radiators and risers may be made with the ordinary short-pattern fittings, as those of the other form are not well adapted to the close connections necessary for this work.

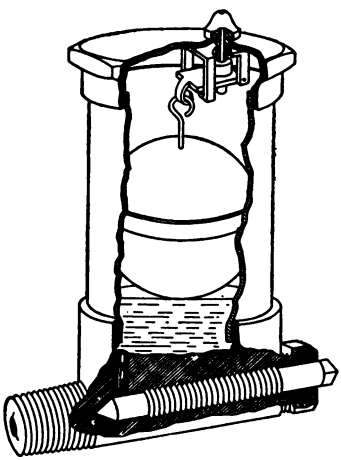


Fig. 104. Automatic Air-Valve for Hot-Water Radiator. Operated by a Float.

Pipe Sizes. The size of pipe required to supply any given radiator depends upon four conditions; *first*, the size of the radiator; *second*, its elevation above the boiler; *third*, the length of pipe required to connect it with the boiler; and *fourth*, the difference in temperature between the supply and the return.

As it would be a long and rather complicated process to work out the required size of each pipe for a heating system, Tables XXVI and XXVII have been prepared, covering the usual conditions to be met with in practice.

TABLE XXVI

Direct Radiating Surface Supplied by Mains of Different Sizes and Lengths of Run

Size of Pipe	Square Feet of Radiating Surface								
	100 ft. Run	200 ft. Run	300 ft. Run	400 ft. Run	500 ft. Run	600 ft Run	700 ft. Run	800 ft. Run	1,000 ft. Run
1 in.	30								
1¼ "	60	50							
1½ "	100	75	50						
2 "	200	150	125	100	75				
2½ "	350	250	200	175	150	125			
3 "	550	400	300	275	250	225	200	175	150
3½ "	850	600	450	400	350	325	300	250	225
4 "	1,200	850	700	600	525	475	450	400	350
5 "		1,400	1,150	1,000	700	850	775	725	650
6 "				1,600	1,400	1,300	1,200	1,150	1,000
7 "							1,706	1,600	1,500

These quantities have been calculated on a basis of 10 feet difference in elevation between the center of the heater and the radiators, and a difference in temperature of 17 degrees between the supply and the return.

TABLE XXVII

Radiating Surface on Different Floors Supplied by Pipes of Different Sizes

Size of Riser	Square Feet of Radiating Surface					
	1st Story	2d Story	3d Story	4th Story	5th Story	6th Story
1 in.	30	55	65	75	85	95
1¼ "	60	90	110	125	140	160
1½ "	100	140	165	185	210	240
2 "	200	275	375	425	500	
2½ "	350	475				
3 "	550					
3½ "	850					

Table XXVI gives the number of square feet of direct radiation which different sizes of mains and branches will supply for varying lengths of run.

Table XXVI may be used for all horizontal mains. For vertical risers or drops, Table XXVII may be used. This has been com-

puted for the same difference in temperature as in the case of Table XXVI (17 degrees), and gives the square feet of surface which different sizes of pipe will supply on the different floors of a building, assuming the height of the stories to be 10 feet. Where a single riser is carried to the top of a building to supply the radiators on the floors below, by drop pipes, we must first get what is called the *average elevation of the system* before taking its size from the table. This may be illustrated by means of a diagram (see Fig. 105).

In *A* we have a riser carried to the third story, and from there a drop brought down to supply a radiator on the first floor. The elevation available for producing a flow in the riser is only 10 feet, the same as though it extended only to the radiator. The water in the two pipes above the radiator is practically at the same temperature, and therefore in equilibrium, and has no effect on the flow of the water in the riser. (Actually there would be some radiation from the pipes, and the return, above the radiator, would be slightly cooler, but for purposes of illustration this may be neglected). If the radiator was on the second floor the elevation of the system would be 20 feet (see *B*); and on the third floor, 30 feet; and so on. The distance which the pipe is carried above the first radiator which it supplies has but little effect in producing a flow, especially if covered, as it should be in practice. Having seen that the flow in the main riser depends upon the elevation of the radiators, it is easy to see that the way in which it is distributed on the different floors must be considered. For example, in *B*, Fig. 105, there will be a more rapid flow through the riser with the radiators as shown, than there would be if they were reversed and the largest one were placed upon the first floor.

We get the average elevation of the system by multiplying the square feet of radiation on each floor by the elevation above the heater, then adding these products together and dividing the same by the total radiation in the whole system. In the case shown in *B*, the average elevation of the system would be

$$\frac{(100 \times 30) + (50 \times 20) + (25 \times 10)}{100 + 50 + 25} = 24 \text{ feet};$$

and we must proportion the main riser the same as though the whole radiation were on the second floor. Looking in Table XXVII, we find, for the second story, that a 1½-inch pipe will supply 140 square

feet; and a 2-inch pipe, 275 feet. Probably a 1½-inch pipe would be sufficient.

Although the height of stories varies in different buildings, 10 feet will be found sufficiently accurate for ordinary practice.

INDIRECT HOT-WATER HEATING

This is used under the same conditions as indirect steam, and the heaters used are similar to those already described. Special

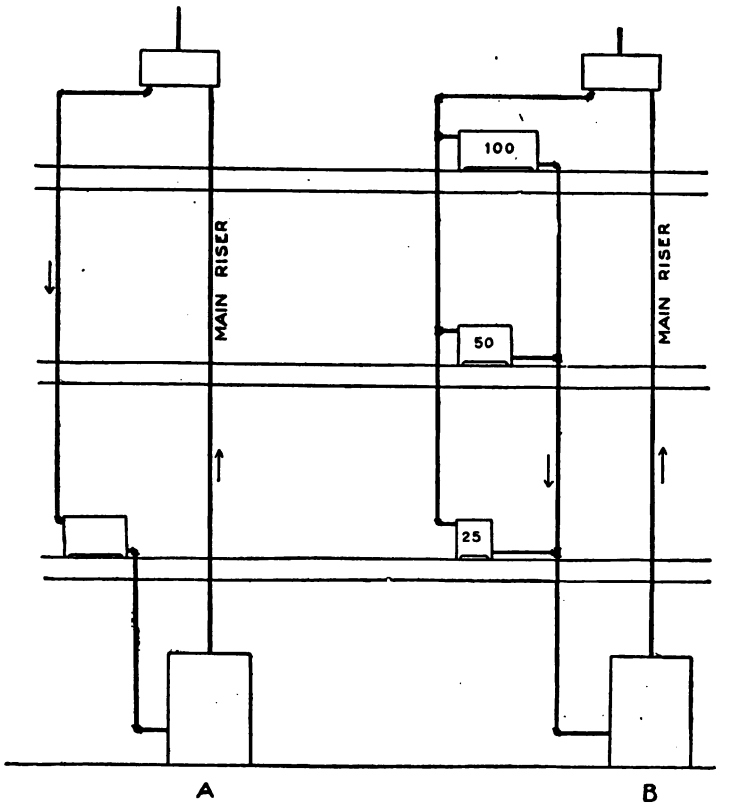


Fig. 105. Diagram to Illustrate Finding of Average Elevation of Heating System.

attention is given to the form of the sections, in order that there may be an even distribution of water through all parts of them. As the stacks are placed in the basement of a building, and only a short distance above the boiler, extra large pipes must be used to secure a proper circulation, for the *head* producing flow is small. The stack

casings, cold-air and warm-air pipes, and registers are the same as in steam heating.

Types of Radiators. The radiators for indirect hot-water heating are of the same general form as those used for steam. Those shown in Figs. 52, 53, 56, 106, and 107 are common patterns. The *drum pin*, Fig. 106, is an excellent form, as the method of making the connections insures a uniform distribution of water through the stack.

Fig. 107 shows a radiator of good form for water circulation, and also of good depth, which is a necessary point in the design of hot-water radiators. They should be not less than 12 or 15 inches deep for good results. Box coils of the form given for steam may also be

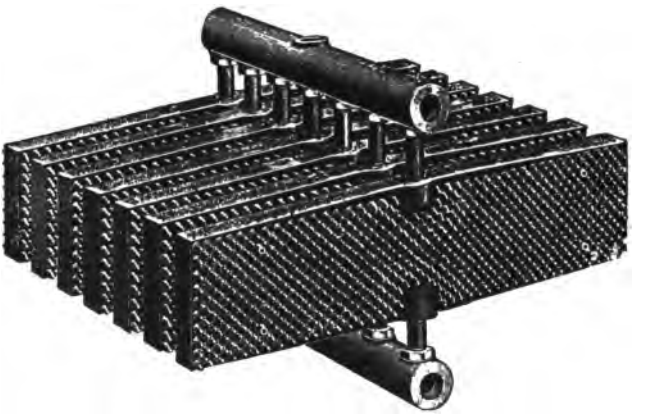


Fig. 106. "Drum Pin" Indirect Hot-Water Radiator.

used, provided the connections for supply and return are made of good size.

Size of Stacks. As indirect hot-water heaters are used principally in the warming of dwelling-houses, and in combination with direct radiation, the easiest method is to compute the surfaces required for direct radiation, and multiply these results by 1.5 for pin radiators of good depth. For other forms the factor should vary from 1.5 to 2, depending upon the depth and proportion of free area for air-flow between the sections.

If it is desired to calculate the required surface directly by the thermal unit method, we may allow an efficiency of from 360 to 400 for good types in zero weather.

In schoolhouse and hospital work, where larger volumes of air are warmed to lower temperatures, an efficiency as high as 500 B. T. U. may be allowed for radiators of good form.

Flues and Casings. For cleanliness, as well as for obtaining the best results, indirect stacks should be hung at one side of the register or flue receiving the warm air, and the cold-air duct should enter beneath the heater at the other side. A space of at least 10 inches, and preferably 12, should be allowed for the warm air above the stack. The top of the casing should pitch upward toward the warm-air outlet at least an inch in its length. A space of from 8 to 10 inches should be allowed for cold air below the stack.

As the amount of air warmed per square foot of heating surface is less than in the case of steam, we may make the flues somewhat smaller as compared with the size of heater. The following proportions may be used under usual conditions for dwelling-houses: $1\frac{1}{2}$ square inches per square foot of radiation for the first floor, $1\frac{1}{4}$ square inches for the second floor, and $1\frac{1}{4}$ square inches for the cold-air duct.

Fig. 107. Indirect Hot-Water Radiator.

Pipe Connections. In indirect hot-water work, it is not desirable to supply more than 80 to 100 square feet of radiation from a single connection. When the requirements call for larger stacks, they should be divided into two or more groups according to size.

It is customary to carry up the main from the boiler to a point near the basement ceiling, where it is air-vented through a small pipe leading to the expansion tank. The various branches should grade downward and connect with the tops of the stacks. In this way, all air, both from the boiler and from the stacks, will find its way to the highest point in the main, and be carried off automatically.

As an additional precaution, a pet-cock air-valve should be placed in the last section of each stack, and brought out through the casing by means of a short pipe.

TABLE XXVIII

Radiating Surface Supplied by Pipes of Various Sizes—Indirect Hot-Water System

Diameter of Pipe	Square Feet of Radiating Surface			
	100 Ft. Run	200 Ft. Run	300 Ft. Run	400 Ft. Run
1 in.	15			
1¼ "	30	25		
1½ "	50	40	25	
2 "	100	75	60	50
2½ "	175	125	100	90
3 "	275	200	150	140
3½ "	425	300	225	200
4 "	600	425	350	300
5 "		700	575	500
6 "				800
7 "				1,200

Some engineers make a practice of carrying the main to the ceiling of the first story, and then dropping to the basement before branching to the stacks, the idea being to accelerate the flow of water through the main, which is liable to be sluggish on account of the small difference in elevation between the boiler and stacks. If the return leg of the loop is left uncovered, there will be a slight drop in temperature, tending to produce this result; but in any case it will be exceedingly small. With supply and return mains of suitable size and properly graded, there should be no difficulty in securing a good circulation in basements of average height.

Pipe Sizes. As the difference in elevation between the stacks and the heater is necessarily small, the pipes should be of ample size to offset the slow velocity of flow through them. The sizes mentioned in Table XXVIII, for runs up to 400 feet, will be found to supply ample radiating surface for ordinary conditions. Some engineers make a practice of using somewhat smaller pipes, but the larger sizes will in general be found more satisfactory.

CARE AND MANAGEMENT OF HOT-WATER HEATERS

The directions given for the care of steam-heating boilers apply in a general way to hot-water heaters, as to the methods of caring for the fires and for cleaning and filling the heater. Only the special points of difference need be considered. Before building the fire, all the pipes and radiators must be full of water, and the expansion tank

should be partially filled as indicated by the gauge-glass. Should the water in any of the radiators fail to circulate, see that the valves are wide open and that the radiator is free from air. Water must always be added at the expansion tank when for any reason it is drawn from the system.

The required temperature of the water will depend upon the outside conditions, and only enough fire should be carried to keep the rooms comfortably warm. Thermometers should be placed in the flow and return pipes near the heater, as a guide. Special forms are made for this purpose, in which the bulb is immersed in a bath of oil or mercury (see Fig. 108).

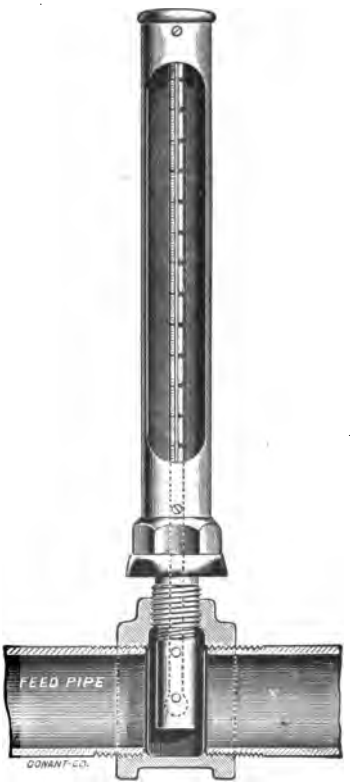


Fig. 108. Thermometer Attached to Feed-Pipe near Heater, to Determine Temperature of Water.

FORCED HOT-WATER CIRCULATION

While the gravity system of hot-water heating is well adapted to buildings of small and medium size, there is a limit to which it can be carried economically. This is due to the slow movement of the water, which calls for pipes of excessive size. To overcome this difficulty, pumps are used to force the water through the mains at a comparatively high velocity.

The water may be heated in a boiler in the same manner as for gravity circulation, or exhaust steam may be utilized in a feed-water heater of large size. Sometimes part of the heat is derived from an economizer placed in the smoke passage from the boilers.

Systems of Piping. The mains for forced circulation are usually run in one of two ways. In the *two-pipe system*, shown in Fig. 109, the supply and return are carried side by side, the former reducing in size, and the latter increasing as the branches are taken off.

The flow through the risers is produced by the difference in pressure in the supply and return mains; and as this is greatest nearest the pump, it is necessary to place throttle-valves in the risers to prevent short-circuiting and to secure an even distribution through all parts of the system.

Fig. 110 shows the *single-pipe* or *circuit system.* This is similar to the one already described for gravity circulation, except that it can be used on a much larger scale.

A single main is carried entirely around the building in this case, the ends being connected with the suction and discharge of the pump as shown.

As the pressure or head in the main drops constantly throughout the circuit, from the discharge of the pump back to the suction, it is

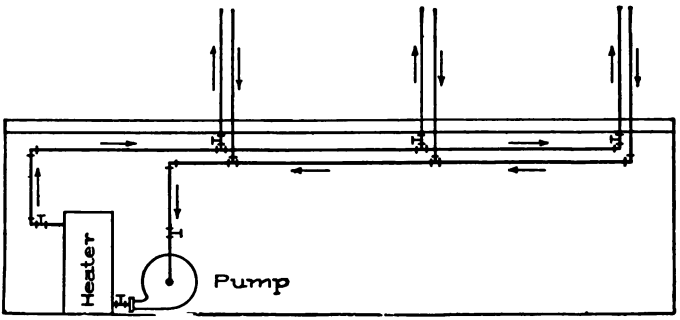


Fig. 109. "Two-Pipe" System for Forced Hot-Water Circulation.

evident that if a supply riser be taken off at any point, and the return be connected into the main a short distance along the line, there will be a sufficient difference in pressure between the two points to produce a circulation through the two risers and the connecting radiators. A distance of 8 or 10 feet between the connections is usually ample to produce the necessary circulation, and even less if the supply is taken from the top of the main and the return connected into the side.

Sizes of Mains and Branches. As the velocity of flow is independent of the temperature and elevation when a pump is used, it is necessary to consider only the volume of water to be moved and the length of run.

The volume is found by the equation.

$$Q = \frac{R\ E}{500\ T},$$

in which

Q = Gallons of water required per minute;
R = Square feet of radiating surface to be supplied;
E = Efficiency of radiating surface in B. T. U. per sq. foot per hour;
T = Drop in temperature of the water in passing through the heating system.

In systems of this kind, where the circulation is comparatively rapid, it is customary to assume a drop in temperature of 30° to 40°, between the supply and return.

Having determined the gallons of water to be moved, the required size of main can be found by assuming the velocity of flow, which for pipes from 5 to 8 inches in diameter may be taken at 400 to 500

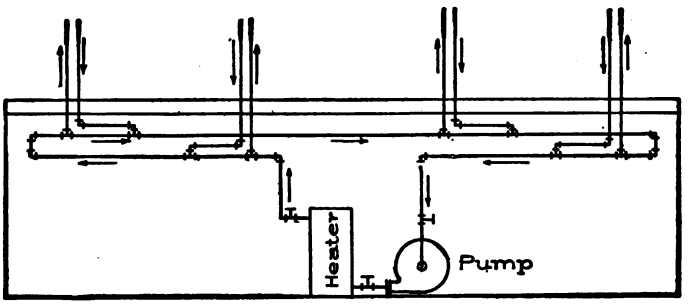


Fig. 110. "Single-Pipe" or "Circuit" System for Forced Hot-Water Circulation.

feet per minute. A velocity as high as 600 feet is sometimes allowed for pipes of large size, while the velocity in those of smaller diameter should be proportionally reduced to 250 or 300 feet for a 3-inch pipe. The next step is to find the pressure or head necessary to force the water through the main at the given velocity. This in general should not exceed 50 or 60 feet, and much better pump efficiencies will be obtained with heads not exceeding 35 or 40 feet.

As the water in a heating system is in a state of equilibrium, the only power necessary to produce a circulation is that required to overcome the friction in the pipes and radiators; and, as the area of the passageways through the latter is usually large in comparison with the former, it is customary to consider only the head necessary to force the water through the mains, taking into consideration the additional friction produced by valves and fittings.

Each long-turn elbow may be taken as adding about 4 feet to the length of pipe; a short-turn fitting, about 9 feet; 6-inch and 4-inch swing check-valves, 50 feet and 25 feet, respectively; and 6-inch and 4-inch globe check-valves, 200 feet and 130 feet, respectively.

Table XXIX is prepared especially for determining the size of mains for different conditions, and is used as follows:

Example. Suppose that a heating system requires the circulation of 480 gallons of water per minute through a circuit main 600 feet in length. The pipe contains 12 long-turn elbows and 1 swing check-valve. What diameter of main should be used?

Assuming a velocity of 480 feet per minute as a trial velocity, we follow along the line corresponding to that velocity, and find that a 5-inch pipe will deliver the required volume of water under a head of 4.9 feet for each 100 feet length of run.

The actual length of the main, including the equivalent of the fittings as additional length, is

$$609 + (12 \times 4) + 50 = 698 \text{ feet};$$

hence the total head required is $4.9 \times 6.98 = 34.2$ feet. As both the assumed velocity and the necessary head come within practicable limits, this is the size of pipe which would probably be used. If it were desired to reduce the power for running the pump, the size of main could be increased. That is, Table XXIX shows that a 6-inch pipe would deliver the same volume of water with a friction head of only about 2 feet per 100 feet in length, or a total head of $2 \times 6.98 = 15.96$, or 16 ft.

The risers in the circuit system are usually made the same size as for gravity work. With double mains, as shown in Fig. 109, they may be somewhat smaller, a reduction of one size for diameters over $1\frac{1}{4}$ inches being common

The branches connecting the risers with the mains may be proportioned from the combined areas of the risers. When the branches are of considerable size, the diameter may be computed from the available head and volume of water to be moved.

Pumps. Centrifugal pumps are usually employed in connection with forced hot-water circulation, in preference to pumps of the piston or plunger type. They are simple in construction, having no valves, produce a continuous flow of water, and, for the low heads

TABLE XXIX

Capacity in Gallons per Minute Discharged at Velocities of 300 to 540 Feet per Minute—Also Friction Head in Feet, per 100 Feet Length of Pipe

	DIAMETER OF PIPE											
	3-Inch		4-Inch		5-Inch		6-Inch		7-Inch		8-Inch	
Velocity	Capacity	Friction	Capacity	Friction	Capacity	Friction	Capacity	Friction	Capacity	Friction	Capacity	Friction
300	110	3.41	195	2.56	306	2.05	440	1.70	600	1.46	783	1.28
480	176	8.16	314	6.12	490	4.9	705	4.08	959	3.49	1,253	3.06
540	198	10.1	352	7.64	550	6.11	794	5.09	1,079	4.36	1,410	3.82

against which they are operated, have a good efficiency. A pump of this type, with a direct-connected engine, is shown in Fig. 111.

Under ordinary conditions the efficiency of a centrifugal pump falls off considerably for heads above 30 or 35 feet; but special high-speed pumps are constructed which work with a good efficiency against 500 feet or more.

Under favorable conditions an efficiency of 60 to 70 per cent is often obtained; but for hot-water circulation it is more common to assume an efficiency of about 50 per cent for the average case.

The horse-power required for driving a pump is given by the following formula:

$$\text{H. P.} = \frac{H \times V \times 8.3}{33{,}000 \times E},$$

in which

H = Friction head in feet;
V = Gallons of water delivered per minute;
E = Efficiency of pump.

Centrifugal pumps are made in many sizes and with varying proportions, to meet the different requirements of capacity and head.

Heaters. If the water is heated in a boiler, any good form may be used, the same as for gravity work. In case tubular boilers are used, the entire shell may be filled with tubes, as no steam space is required.

In order to prevent the water from passing in a direct line from the inlet to the outlet, a series of baffle-plates should be used to bring it in contact with all parts of the heating surface.

When steam is used for heating the water, it is customary to employ a closed feed-water heater with the steam on the inside of the tubes and the water on the outside.

Any good form of heater can be used for this purpose by providing it with steam connections of sufficient size. In the ordinary form of heater, the feed-water flows through the tubes, and the connections are therefore small, making it necessary to substitute special nozzles of large size when used in the manner here described.

When computing the required amount of heating surface in the tubes of a heater, it is customary to assume an efficiency of about 200 B. T. U. per square foot of surface per hour, per degree difference in temperature between the water and steam.

It is usual to circulate the water at a somewhat higher temperature in systems of this kind, and a maximum initial temperature of 200 degrees, with a drop of 40 degrees in the heating system, may be used in computing the size of heater. If exhaust steam is used at atmospheric pressure, there will be a difference of 212 − 180 = 32 degrees, between the *average* temperature of the water and the steam, giving an efficiency of 200 × 32 = 6,400 B. T. U. per square foot of heating surface.

From this it is evident that 6,400 ÷ 170 = 38 square feet of direct radiating surface, or 6,400 ÷ 400 = 16 square feet of indirect, may be supplied from each square foot of tube surface in the heater.

Example. A building having 6,000 square feet of direct, and 2,000 square feet of indirect radiation, is to be warmed by hot water under forced circulation. Steam at atmospheric pressure is to be used for heating the water. How many square feet of heating surface should the heater contain?

6,000 ÷ 38 = 158; and 2,000 ÷ 16 = 125; therefore, 158 + 125 = 283 square feet, the area of heating surface called for.

When the exhaust steam is not sufficient for the requirements, an auxiliary live steam heater is used in connection with it.

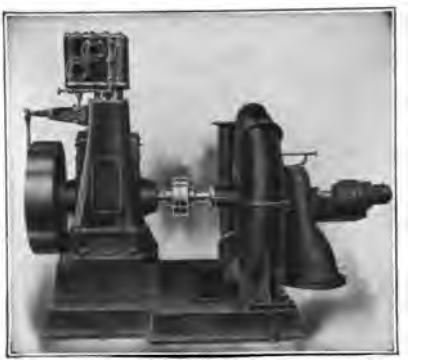


Fig. 111. Centrifugal Pump Direct-Connected to Engine, for Forced Hot-Water Circulation.
Courtesy of Jeansville Iron Works Company, Chicago.

EXAMPLES FOR PRACTICE

1. A building contains 10,000 square feet of direct radiation and 4,000 square feet of indirect radiation. How many gallons of water must be circulated through the mains per minute, allowing a drop in temperature of 40 degrees? ANS. 165 gal.

2. In the above example, what size of main should be used, assuming the circuit to be 300 feet in length and to contain ten long-turn elbows? The friction head is not to exceed 10 ft., and the velocity of flow not to exceed 300 feet per minute. ANS. 4-inch.

3. What horse-power will be required to drive a centrifugal pump delivering 400 gallons per minute against a friction head of 40 feet, assuming an efficiency of 50 per cent for the pump?
ANS. 8 H. P.

4. A building contains 10,000 square feet of direct radiation and 5,000 square feet of indirect radiation. Steam at atmospheric pressure is to be used. The initial temperature of the water is to be 200°; and the final 160°. How many square feet of heating surface should the heater contain? ANS. 575 sq. ft.

5. How many square feet would be required in the above heater (Example 4) if the initial temperature of the water were 180° and the final temperature 150°? ANS. 399 sq. ft.

EXHAUST-STEAM HEATING

Steam, after being used in an engine, contains the greater part of its heat; and if not condensed or used for other purposes, it can usually be employed for heating without affecting to any great extent the power of the engine. In general, we may say that it is a matter of economy to use the exhaust for heating, although various factors must be considered in each case to determine to what extent this is true. The more important considerations bearing upon the matter are: the relative quantities of steam required for power and for heating; the length of the heating season; the type of engine used; the pressure carried; and, finally, whether the plant under consideration is entirely new, or whether, on the other hand, it involves the adapting of an old heating system to a new plant.

The first use to be made of the exhaust steam is the heating of the feed-water, as this effects a constant saving both summer and winter, and can be done without materially increasing the back-pressure on the engine. Under ordinary conditions, about one-sixth of the steam supplied to the engine can be used in this way, or more nearly one-fifth of the exhaust *discharged* from the engine.

We may assume in average practice that about 80 per cent of the steam supplied to an engine is discharged in the form of steam at a lower pressure, the remaining 20 per cent being partly converted into work and partly lost through cylinder condensation. Taking this into account, there remains, after deducting the steam used for feed-water heating, $.8 \times \frac{4}{5} = .64$ of the entire quantity of steam supplied to the engine, available for heating purposes.

When the quantity of steam required for heating is small compared with the total amount supplied to the engine, or where the heating season is short, it is often more economical to run the engine

condensing and use the live steam for heating. This can be determined in any particular case by computing the saving in fuel by the use of a condenser, taking into account the interest and depreciation on the first cost of the condensing apparatus, and the cost of water, if it must be purchased, and comparing it with the cost of heating with live steam.

Usually, however, in the case of office buildings and institutions, and commonly in the case of shops and factories, especially in northerly latitudes, it is advantageous to use the exhaust for heating, even if a condenser is installed for summer use only. The principal objection raised to the use of exhaust steam has been the higher back-pressure required on the engines, resulting in a loss of power nearly proportional to the ratio of the back-pressure to the mean effective pressure. There are two ways of offsetting this loss—one, by raising the initial or boiler pressure; and the other, by increasing the cut-off of the engine. Engines are usually designed to work most economically at a given cut-off, so that in most cases it is undesirable to change it to any extent. Raising the boiler pressure, on the other hand, is not so objectionable if the increase amounts to only a few pounds.

Under ordinary conditions in the case of a simple engine, a rise of 3 pounds in the back-pressure calls for an increase of about 5 pounds in the boiler pressure, to maintain the same power at the engine.

The indicator card shows a back-pressure of about 2 pounds when an engine is exhausting into the atmosphere, so that an increase of 3 pounds would bring the pressure up to a total of 5 pounds which should be more than sufficient to circulate the steam through any well-designed heating system.

If it is desired to reduce rather than increase the back-pressure, one of the so-called *vacuum systems*, described later, can be used.

The systems of steam heating which have been described are those in which the water of condensation flows back into the boiler by gravity. Where exhaust steam is used, the pressure is much below that of the boiler, and it must be returned either by a pump or by a return trap. The exhaust steam is often insufficient to supply the entire heating system, and must be supplemented by live steam taken directly from the boiler. This must first pass through a reducing

valve in order to reduce the pressure to correspond with that carried in the heating system.

An engine does not deliver steam continuously, but at regular intervals, at the end of each stroke; and the amount is likely to vary with the work done, since the governor is adjusted to admit steam in such a quantity as is required to maintain a uniform speed. If the work is light, very little steam will be admitted to the engine; and for this reason the supply available for heating may vary somewhat, depending upon the use made of the power delivered by the engine. In mills the amount of exhaust steam is practically constant; in office buildings where power is used for lighting, the variation is greater, especially if power is also required for the running of elevators.

The general requirements for a successful system of exhaust steam heating include a system of piping of such proportions that only a slight increase in back-pressure will be thrown upon the engine; a connection which shall automatically supply live steam at a reduced pressure as needed; provision for removing the oil from the exhaust steam; a relief or back-pressure valve arranged to prevent any sudden increase in back pressure on the engine; and a return system of some kind for returning the water of condensation to the boiler against a higher pressure. These requirements may be met in various ways, depending upon actual conditions found in different cases.

To prevent sudden changes in the back-pressure, due to irregular supply of steam, the exhaust pipe from the engine is often carried to a closed tank having a capacity from 30 to 40 times that of the engine cylinder. This tank may be provided with baffle-plates or other arrangements and may serve as a separator for removing the oil from the steam as it passes through.

Any system of piping may be used; but great care should be taken that as little resistance as possible is introduced at bends and fittings; and the mains and branches should be of ample size. Usually the best results are obtained from the system in which the main steam pipe is carried directly to the top of the building, the distributing pipes being run from that point, and the radiating surfaces supplied by a down-flowing current of steam.

Before taking up the matter of piping in detail a few of the more important pieces of apparatus will be described in a brief way.

Reducing Valves. The action of pressure-reducing valves has

been taken up quite fully in "Boiler Accessories," and need not be repeated here. When the reduction in pressure is large, as in the case of a combined power and heating plant, the valve may be one or two sizes smaller than the low-pressure main into which it discharges. For example, a 5-inch valve will supply an 8-inch main, a 4-inch a 6-inch main, a 3-inch a 5-inch main, a 2½-inch a 4-inch main, etc.

For the smaller sizes, the difference should not be more than one size. All reducing valves should be provided with a valved by-pass for cutting out the valve in case of repairs. This connection is usually made as shown in plan by Fig. 112.

Grease Extractor. When exhaust steam is used for heating purposes, it must first be passed through some form of separator for removing the oil; and as an additional precaution it is well to pass the

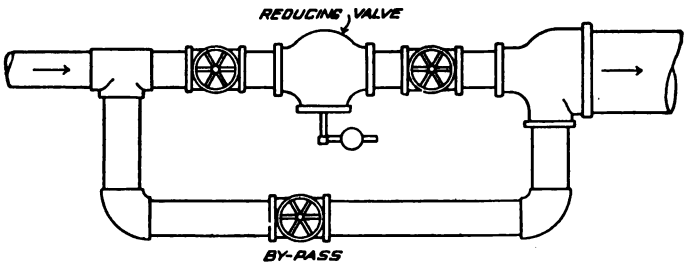


Fig. 112. Connections of Reducing Valve in Exhaust-Steam Heating System.

water of condensation through a separating tank before returning it to the boilers.

Such an arrangement is shown in Fig. 113. As the oil collects on the surface of the water in the tank, it can be made to overflow into the sewer by closing the valve in the connection with the receiving tank, for a short time.

As much of the oil as possible should be removed before the steam enters the pipes and radiators, else a coating will be formed on their inner surfaces, which will reduce their heating efficiency. The separation of the oil is usually effected by introducing a series of baffling plates in the path of the steam; the particles of oil striking these are stopped, and thus separated from the steam. The oil drops into a receiver provided for this purpose and is discharged through a trap to the sewer.

In the separator, or extractor, shown in Fig. 114, the separation is accomplished by a series of plates placed in a vertical position in the

body of the separator, through which the steam must pass. These plates consist of upright hollow columns, with openings at regular intervals for the admission of water and oil, which drain downward to the receiver below. The steam takes a zigzag course, and all of it comes in contact with the intercepting plates, which insures a thorough separation of the oil and other solid matter from the steam. Another form, shown in Fig. 115, gives excellent results, and has the advantage of providing an equalizing chamber for overcoming, to some extent, the unequal pressure due to the varying load on the engine. It consists of a tank or receiver about 4 feet in diameter, with heavy boiler-iron heads slightly crowned to give stiffness.

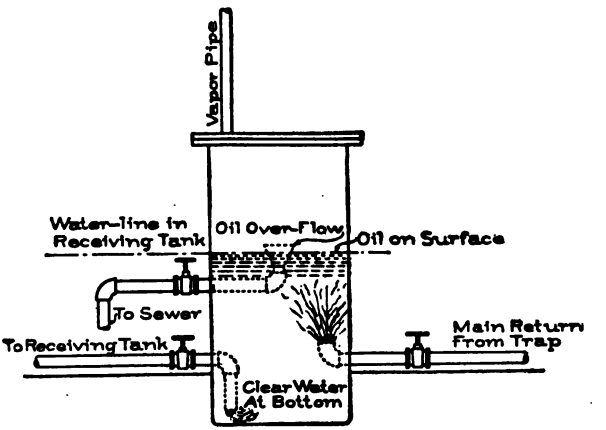


Fig. 113. Separator for Removing Oil from Exhaust Steam and Water Condensation.

Through the center is a layer of excelsior (wooden shavings of long fibre) about 12 inches in thickness, supported on an iron grating, with a similar grating laid over the top to hold it in place. The steam enters the space below the excelsior and passes upward, as shown by the arrows. The oil is caught by the excelsior, which can be renewed from time to time as it becomes saturated. The oil and water which fall to the bottom of the receiver are carried off through a trap. Live steam may be admitted through a reducing valve, for supplementing the exhaust when necessary.

Back-Pressure Valve. This is a form of relief valve which is placed in the outboard exhaust pipe to prevent the pressure in the heating system from rising above a given point. Its office is the

reverse of the reducing valve, which supplies more steam when the pressure becomes too low. The form shown in Fig. 116 is designed for a vertical pipe. The valve proper consists of two discs of unequal area, the combined area of which equals that of the pipe. The force tending to open the valve is that due to the steam pressure acting on an area equal to the difference in area between the two discs: it is clear from the cut that the pressure acting on the larger disc tends to open the valve while the pressure on the smaller acts in the opposite direction. The valve-stem is connected by a link and crank arm with a spindle upon which is a lever and weight outside. As the valve opens, the weight is raised, so that, by placing it in different positions on the lever arm, the valve will open at any desired pressure.

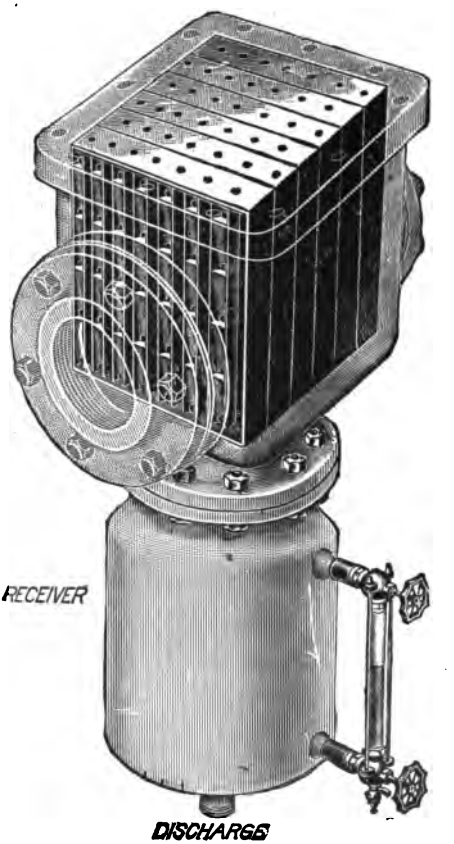


Fig. 114. Oil Separator Consisting of Vertical Plates with Openings Giving Steam a Zigzag Course.

Fig. 117 shows a different type, in which a spring is used instead of a weight. This valve has a single disc moving in a vertical direction. The valve stem is in the form of a piston or dash-pot which prevents a too sudden movement and makes it more quiet in its action. The disc is held on its seat against the steam pressure by a lever attached to the spring as shown. When the pressure of the steam on the underside becomes greater than the tension of the spring, the valve lifts and allows the steam to escape. The tension of the spring can be varied by means of the adjusting screw at its upper end.

A back-pressure valve is simply a low-pressure safety-valve

designed with a specially large opening for the passage of steam through it. These valves are made for horizontal as well as for vertical pipes.

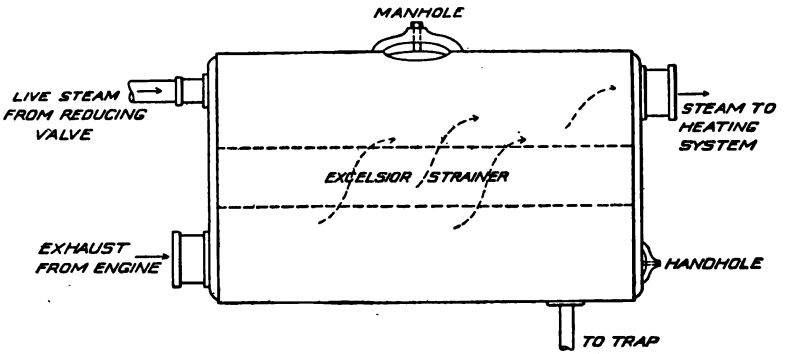


Fig. 115. Oil Separator Consisting of a Tank in which Steam is Filtered by Passing Upward through a Layer of Excelsior.

Exhaust Head. This is a form of separator placed at the top of an outboard exhaust pipe to prevent the water carried up in the steam from falling upon the roofs of buildings or in the street below. Fig. 118 is known as a centrifugal exhaust head. The steam, on entering at the bottom, is given a whirling or rotary motion by the spiral deflectors; and the water is thrown outward by centrifugal force against the sides of the chamber, from which it flows into the shallow trough at the base, and is carried away through the drip-pipe, which is brought down and connected with a drain-pipe inside the building. The passage of the steam outboard is shown by the arrows. Other forms are used in which the water is separated from the steam by deflectors which change the direction of the currents.

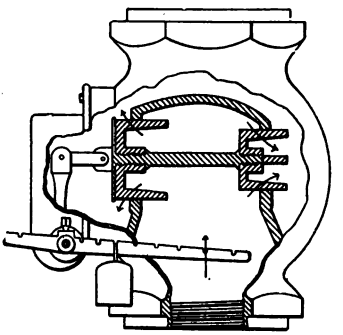


Fig. 116. Automatically Acting Back-Pressure Valve Attached to Vertical Pipe. For Preventing Rise of Pressure in System above any Desired Point.

Automatic Return-Pumps. In exhaust heating plants, the condensation is returned to the boilers by means of some form of return-pump. A combined pump and receiver of the form illus-

trated in Fig. 119 is generally used. This consists of a cast-iron or wrought-iron tank mounted on a base in connection with a boiler feed-pump. Inside the tank is a ball-float connected by means of levers with a valve in the steam pipe which is connected with the pump. When the water-line in the tank rises above a certain level, the float is raised and opens the steam valve, which starts the pump. When the water is lowered to its normal level, the valve closes and the pump stops. By this arrangement, a constant water-line is maintained in the receiver, and the pump runs only as needed to care for the condensation as it returns from the heating system. If dry returns are used, they may be brought together and connected with the top of the receiver. If it is desired to seal the horizontal runs, as

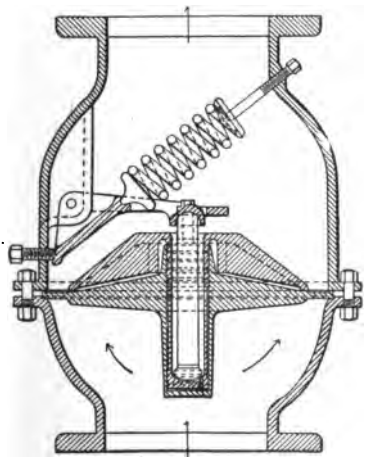


Fig. 117. Back-Pressure Valve Automatically Operated by a Spring.

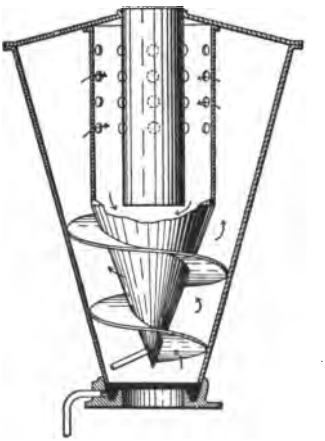


Fig. 118. Centrifugal Exhaust Head.

is usually the case, the receiver may be raised to a height sufficient to give the required elevation and the returns connected near the bottom below the water-line.

A *balance-pipe*, so called, should connect the heating main with the top of the tank, for equalizing the pressure; otherwise the steam above the water would condense, and the vacuum thus formed would draw all the water into the tank, leaving the returns practically empty and thus destroying the condition sought. Sometimes an independent regulator or pump governor is used in place of a receiver. One type is shown in Fig. 120. The return main is connected at

the upper opening, and the pump suction at the lower. A float inside the chamber operates the steam valve shown at the top, and the pump works automatically as in the case just described.

If it is desired to raise the water-line, the regulator may be elevated to the desired height and connections made as shown in Fig. 121.

Return Traps. The principle of the return trap has been described in "Boiler Accessories," but its practical form and application

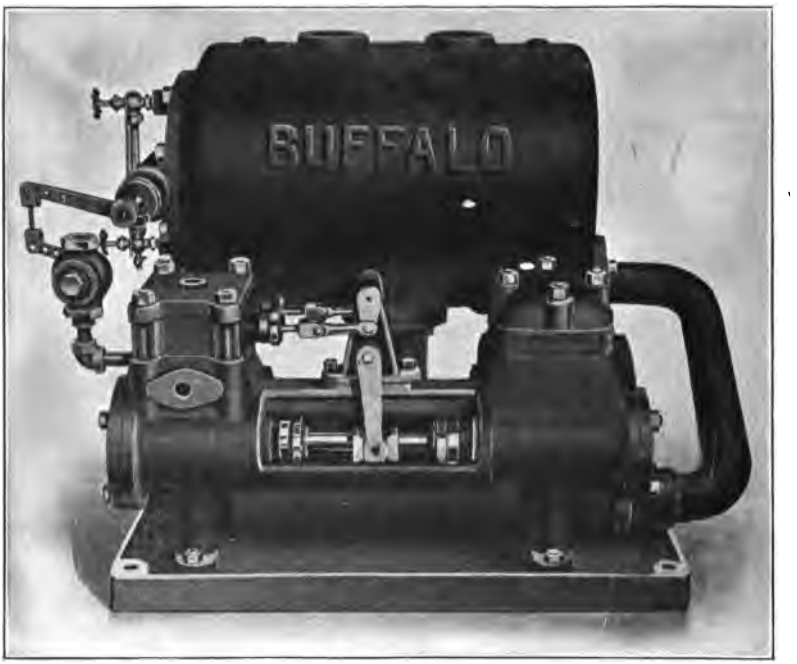


Fig. 119. Buffalo Duplex Automatic Feed Pump and Receiver for Returning Water of Condensation to Boiler.
Courtesy of Buffalo Forge Company, Buffalo, New York.

will be taken up here. The type shown in Fig. 122 has all its working parts outside the trap. It consists of a cast-iron bowl pivoted at *G* and *H*. There is an opening through *G* connecting with the inside of the bowl. The pipe *K* connects through *C* with an interior pipe opening near the top (see Fig. 123). The pipe *D* connects with a receiver, into which all the returns are brought. *A* is a check-valve allowing water to pass through in the direction shown by the arrow. *E* is a pipe connecting with the boiler below the water-line. *B* is a

check opening toward the boiler, and K, a pipe connected with the steam main or drum.

The action of the trap is as follows: As the bowl fills with water from the receiver, it overbalances the weighted lever and drops to the bottom of the ring. This opens the valve C, and admits steam at boiler pressure to the top of the trap. Being at a higher level the water flows by gravity into the boiler, through the pipe E. Water and steam are kept from passing out through D by the check A.

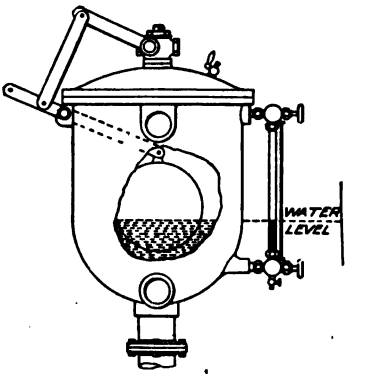


Fig. 120. Automatic Float-Operated Pump Governor Used instead of a Receiver.

When the trap has emptied itself, the weight of the ball raises it to the original position, which movement closes the valve C and opens the small vent F. The pressure in the bowl being relieved, water flows in from the receiver through D, until the trap is filled, when the

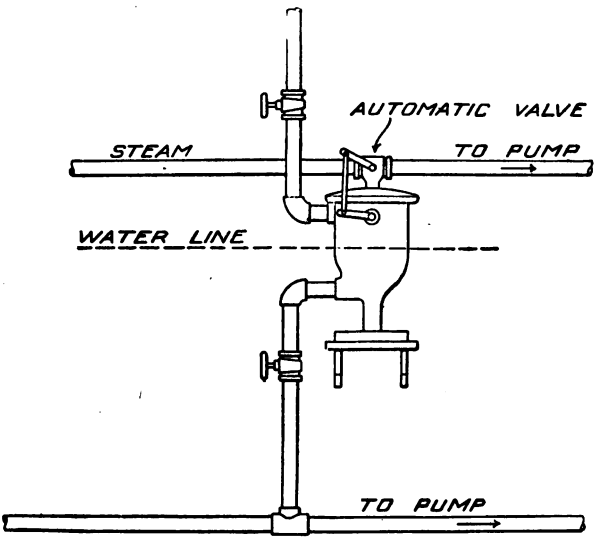


Fig. 121. Pump Regulator Placed at Sufficient Height to Raise Water-Line to Point Desired.

process is repeated. In order to work satisfactorily, the trap should be placed at least 3 feet above the water-level in the boiler, and the

pressure in the returns must always be sufficient to raise the water from the receiver to the trap against atmospheric pressure, which is theoretically about 1 pound for every 2 feet in height. In practice there will be more or less friction to overcome, and suitable adjustments must be made for each particular case.

Fig. 124 shows another form of trap acting upon the same principle, except that in this case the steam valve is operated by a bucket or float inside the trap. The pipe connections are practically the same as with the trap just described.

Return traps are more commonly used in smaller plants where it is desired to avoid the expense and care of a pump.

Fig. 122. Return Trap with Working Parts External.

Damper-Regulators. Every heating and every power plant should be provided with automatic means for closing the dampers when the steam pressure reaches a certain point, and for opening them again when the pressure drops. There are various regulators designed for this purpose, a simple form of which is shown in Fig. 125.

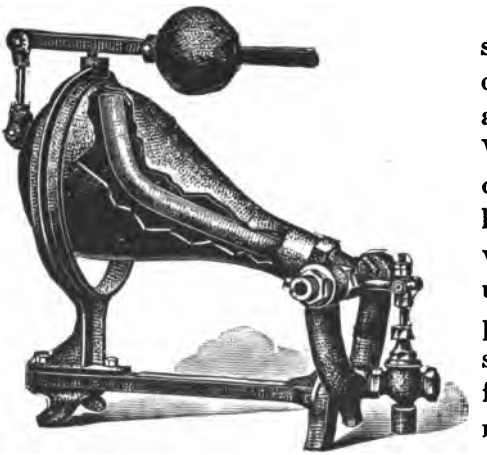


Fig. 123. Showing Interior Detail of Return Trap of Fig. 122.

Steam at boiler pressure is admitted beneath a diaphragm which is balanced by a weighted lever. When the pressure rises to a certain point, it raises the lever slightly and opens a valve which admits water under pressure above a diaphragm located near the smoke-pipe. This action forces down a lever connected by chains with the damper, and closes it. When the steam pressure drops, the water-valve is closed, and the different parts of the apparatus take their original positions.

Another form similar in principle is shown in Fig. 126. In this

case a piston is operated by the water-pressure, instead of a diaphragm. In both types the pressures at which the damper shall open and close are regulated by suitable adjustments of the weights upon the levers.

Pipe Connections. The method of making the pipe connections in any particular case will depend upon the general arrangement of the apparatus and the various conditions. Fig. 127 illustrates

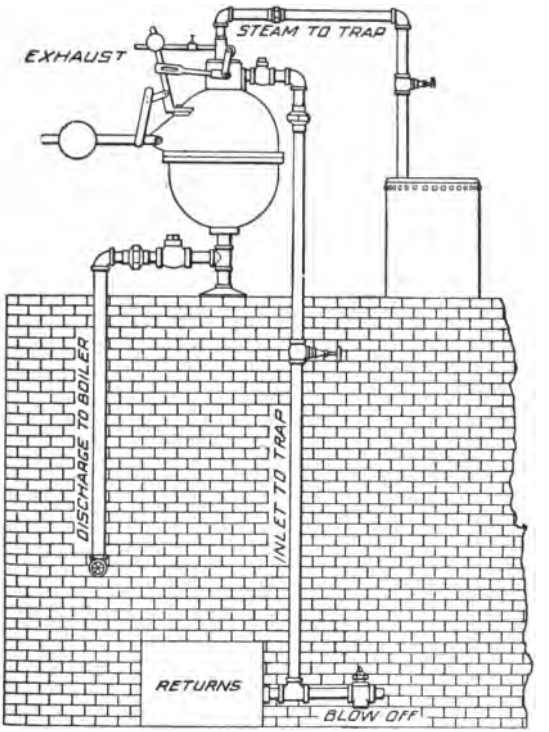


Fig. 124. Return Trap with Steam Valve Operated by Bucket or Float Inside.

the general principles to be followed, and by suitable changes may be used as a guide in the design of new systems.

Steam first passes from the boilers into a large drum or header. From this, a main, provided with a shut-off valve, is taken as shown; one branch is carried to the engines, while another is connected with the heating system through a reducing valve having a by-pass and cut-out valves. The exhaust from the engines connects with the large main over the boilers at a point just above the steam drum. The

branch at the right is carried outboard through a back-pressure valve which may be set to carry any desired pressure on the system. The other branch at the left passes through an oil separator into the heating system. The connections between the mains and radiators are made in the usual way, and the main return is carried back to the return pump near the floor. A false water-line or seal is obtained by elevating the pump regulator as already described. An equalizing

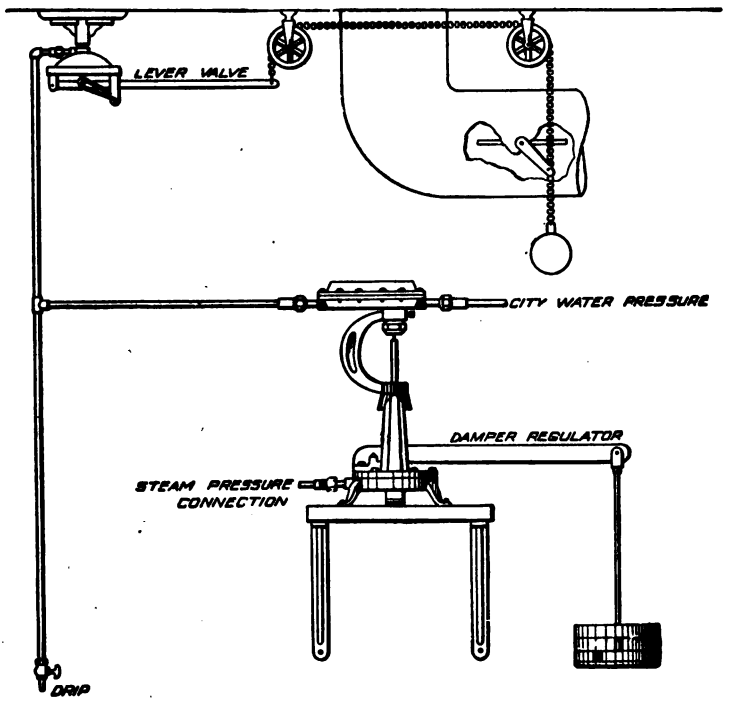


Fig. 125. Simple Form of Automatic Damper-Regulator, Operated by Lever Attached to Diaphragm, for Closing Dampers when Steam Pressure Reaches a Certain Point.

or balance pipe connects the top of the regulator with the low-pressure heating main, and high pressure is supplied to the pump as shown.

A sight-feed lubricator should be placed in this pipe above the automatic valve; and a valved by-pass should be placed around the regulator, for running the pump in case of accident or repairs. The oil separator should be drained through a special oil trap to a catch-basin or to the sewer; and the steam drum or any other low points

or pockets in the high-pressure piping should be dripped to the return tank through suitable traps.

Means should be provided for draining all parts of the system to the sewer, and all traps and special apparatus should be by-passed. The return-pump should always be duplicated in a plant of any size, as a safeguard against accident; and the two pumps should be run alternately, to make sure that one is always in working order.

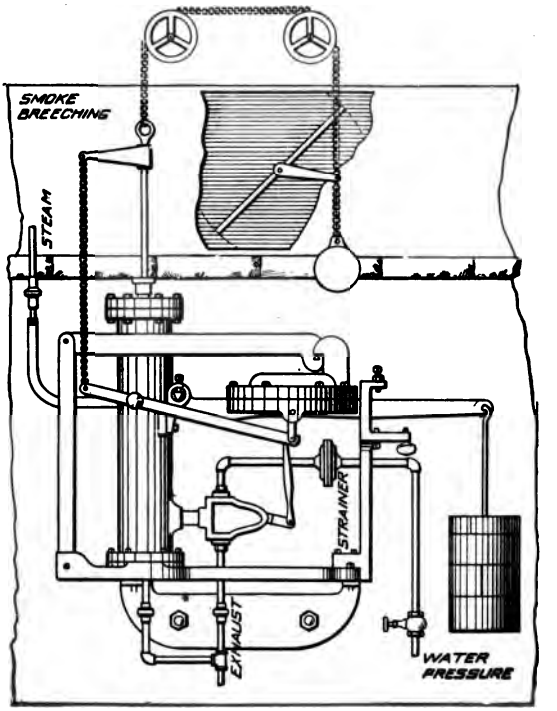


Fig. 126. Automatic Damper-Regulator Operated by Piston Actuated by Water-Pressure.

One piece of apparatus not shown in Fig. 127 is the feed-water heater. If all of the exhaust steam can be utilized for heating purposes, this is not necessary, as the cold water for feeding the boilers may be discharged into the return pipe and be pumped in with the condensation. In summertime, however, when the heating plant is not in use, a feed-water heater is necessary, as a large amount of heat

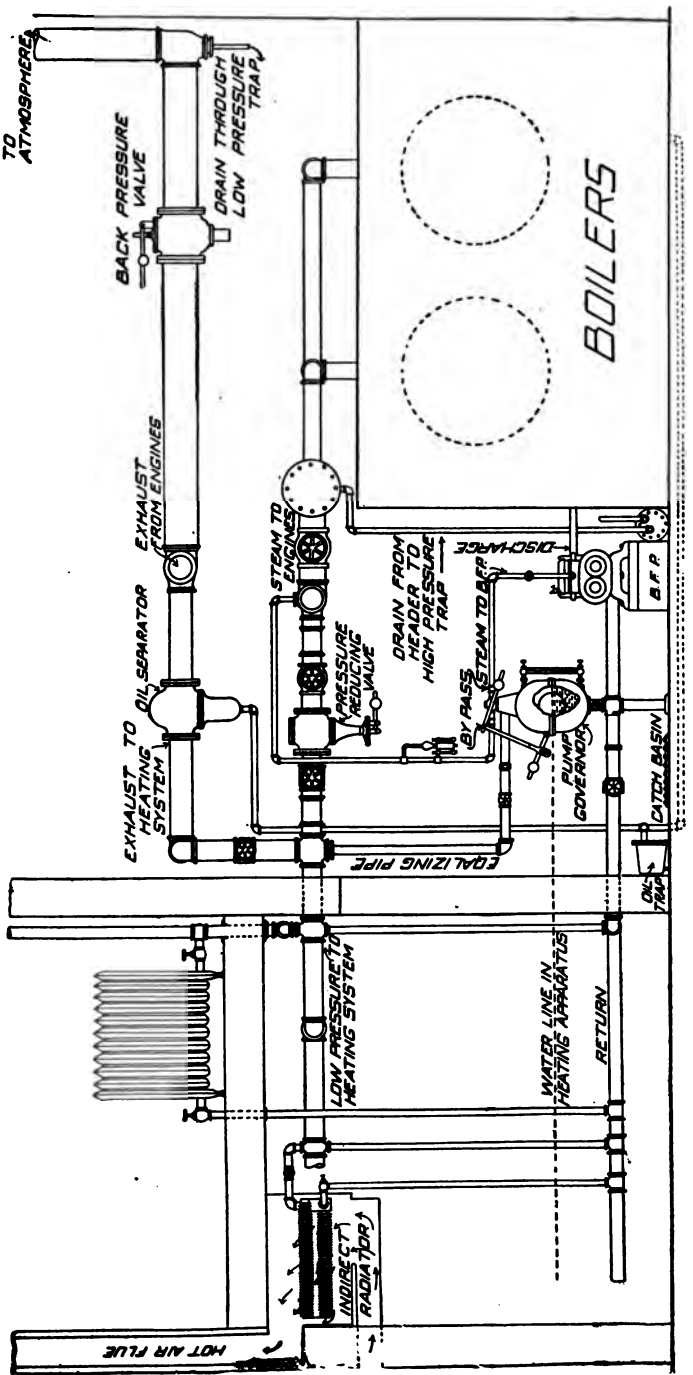
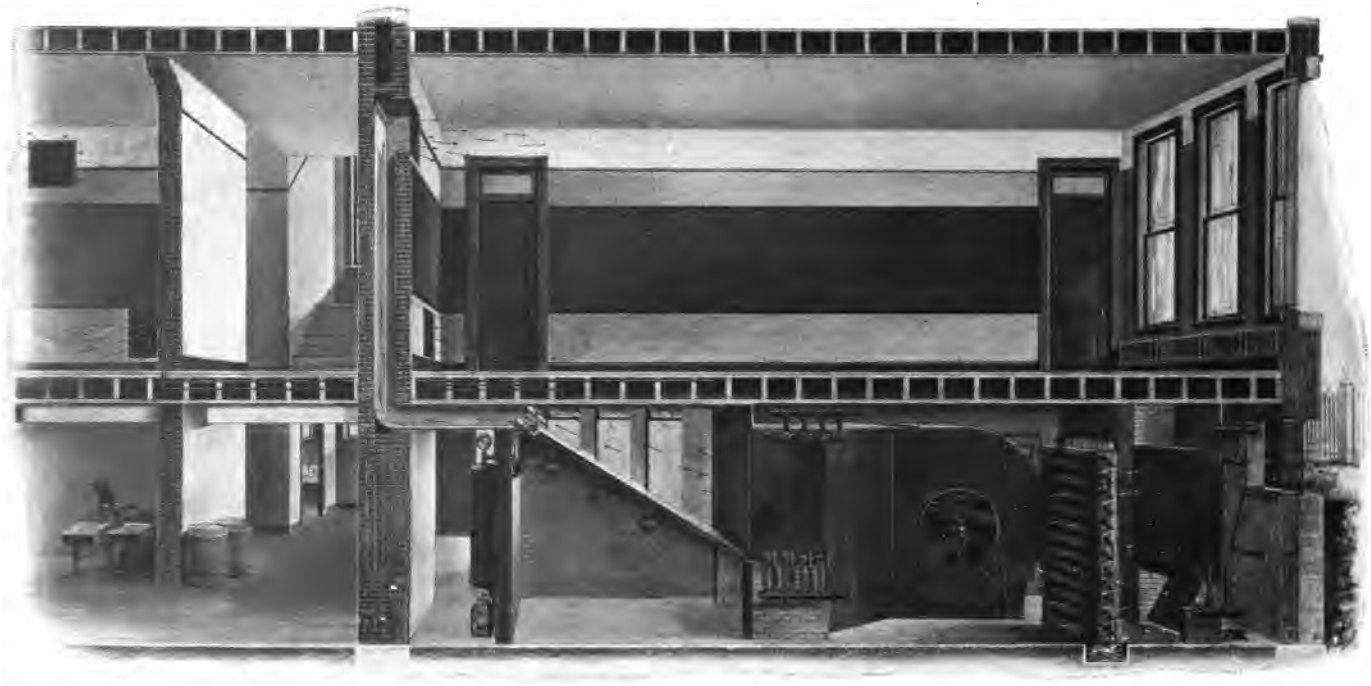


Fig. 127. General Method of Making Pipe Connections for Exhaust-Steam Heating.

which would otherwise be wasted may be saved in this way. The connections will depend somewhat upon the form of heater used; but in general a single connection with the heating main inside the back-pressure valve is all that is necessary. The condensation from the heater should be trapped to the sewer.



SECTIONAL VIEW OF BUILDING EQUIPPED WITH VENTO CAST-IRON HOT-BLAST HEATERS
Installation Shows Method of Warming and Ventilating a School Building
Courtesy of American Radiator Company, Chicago

STEAM AND HOT WATER FITTING

STEAM BOILERS AND CONNECTIONS

Small Cast-Iron Boilers. For small low-pressure steam heating jobs, boilers made up of very few sections are used. Two types are illustrated in Figs. 1 and 2. The ratings of such boilers range, as a rule, from about 200 square feet to 800 square feet. These figures and those following are intended to give merely a general idea of the capacities of boilers of various types. There is no hard and fast rule governing the matter, manufacturers varying greatly in their practice. The ratings mentioned are given in the number of square feet of direct radiation the boiler is rated to supply, with steam at from 3 to 5 pounds' pressure when the radiators are surrounded by air at 70° F.

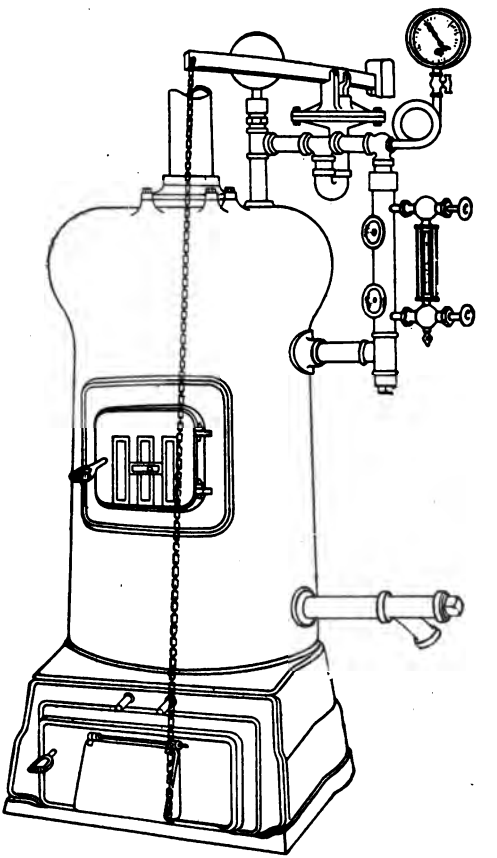


Fig. 1. Small Low-Pressure Steam Heating Boiler.

Boilers similar, in a general way, to the one illustrated in Fig. 3 are used for jobs somewhat larger than the boilers above described would be adapted to. These

boilers have grates ranging generally from 18 inches to 36 inches diameter, and are rated from about 300 square feet to 1,600 square feet, or more.

Cast-Iron Boilers with Vertical Sections. The boilers just described have the disadvantage of not being capable of having their grate surface increased by adding sections, as may readily be done with boilers having vertical sections.

Boilers for jobs having anywhere from 500 to 5,000 square feet of surface, or more, are made up of vertical sections, as in Fig. 4, connected either by slip nipples or by drums and nipples with long screws and lock-nuts. Very many slip-nipple boilers are now being manufactured owing to ease of erection.

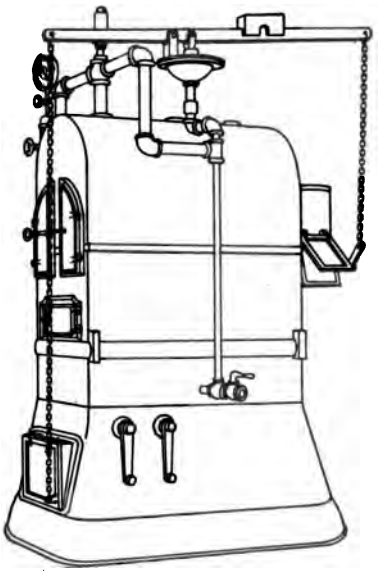


Fig. 2. Small Low-Pressure Steam Heating Boiler

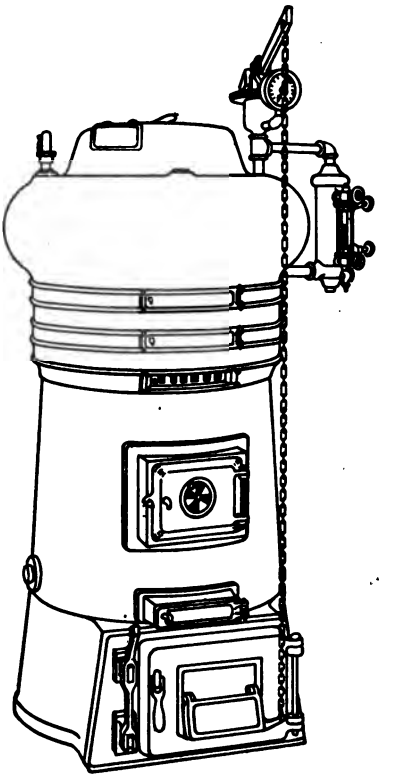


Fig. 3. Steam Heating Boiler

The larger sizes of vertical sectional boilers are often made up of two sets of sections placed opposite each other, as shown in Fig. 5. Such boilers are rated up to 6,000 square feet and over.

The manufacturers of cast-iron boilers have overrated the

capacity of their boilers for an installation in which there is a relatively long time between firings, say 8 or 10 hours, such as in residences. On this account, a well-designed heating system demands, for such cases, the selection of a boiler whose manufacturer's rating is from 40 to 50 per cent in excess of the calculated radiation required.

Arrangement of Grates. Certain makers, in order to avoid making patterns for a boiler with a wide grate, secure the necessary grate surface by adding to the length. For ordinary low-pressure heating, the efficiency of any grate over 6 feet in length falls off very rapidly, owing to the difficulty of properly caring for the fire. Six feet should be considered about the limit for the length of a grate in a low-pressure boiler.

Not long ago few portable boilers with grates wider than 36 inches were manufactured. Now, boilers with 42-inch, 48-inch, and even wider grates, are common.

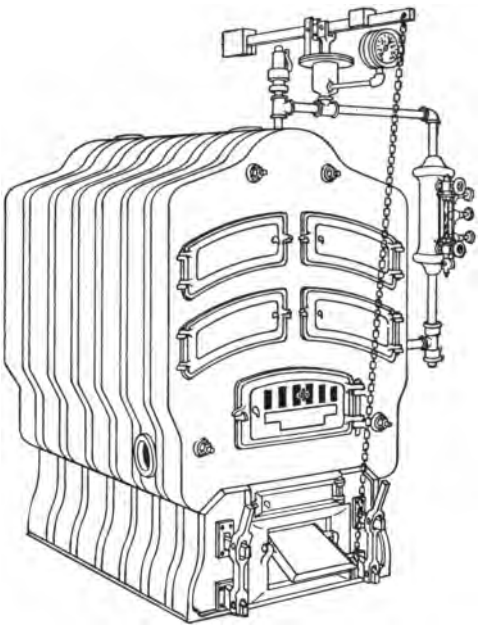


Fig. 4. Steam Heating Boiler with Vertical Sections

Selection of Boilers. It is well in selecting a boiler, to see that the proportion of heating surface to grate surface is not less than 16 to 1, and in large boilers not less than 20 to 1; that the fire-box is deep, so that ample coal may be put on to burn through the night; that the grate is not too long for convenient firing and cleaning; that there is ample steam space; and that the water line is not broken into too many small areas involving the likelihood that water will be lifted by rapid evaporation and wet steam result. See to it, also, that the ash-pit is deep, and that the grate is of a design that will permit convenient operation of the boiler.

On large jobs, it is better, as a rule, to use two boilers. One

must remember that a plant must be designed for the coldest weather; and since the average temperature during the heating season is, in many Northern sections, not far from 40°, one of a pair of boilers will be sufficient under average conditions to do the work with economy; whereas a single, large boiler, during a good part of the heating season, would have to be run with drafts checked and under very unfavorable conditions as to economy. It is almost as poor economy to have too large a boiler as to have one too small.

Boilers for Soft Coal. Some boilers for burning soft coal are arranged with a perforated pipe or duct discharging heated air above the fire to make the combustion more complete and thus diminish the

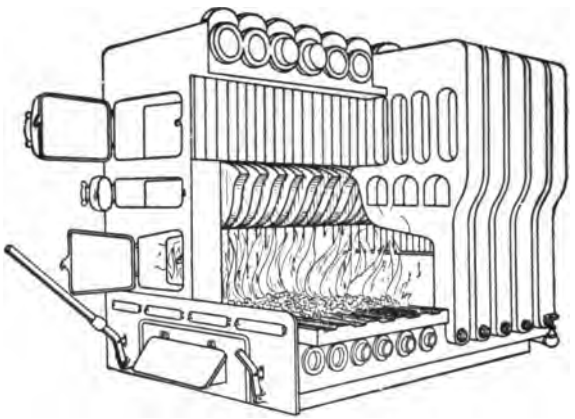


Fig. 5. Vertical Sectional Boiler

amount of smoke given off. This arrangement is of somewhat doubtful utility, since it is difficult to heat the air properly, and to regulate its admission. It is necessary, for soft coal boilers, that the flues and smoke-pipe be larger than for hard coal heaters, in order to provide for the more rapid accumulation of soot.

Down-draft boilers for the use of soft coal are being used very extensively in soft coal districts. In down-draft boilers, the air is drawn down through the fire, which is on a water-cooled grate, instead of passing upward in the usual manner. These boilers are made in the vertical sectional cast-iron type and also in the steel fire-box type of boiler. The fire-box boiler is used generally in larger installations of from 4,000 to 10,000 square feet of radiation.

The down-draft boilers require a more intense draft than the

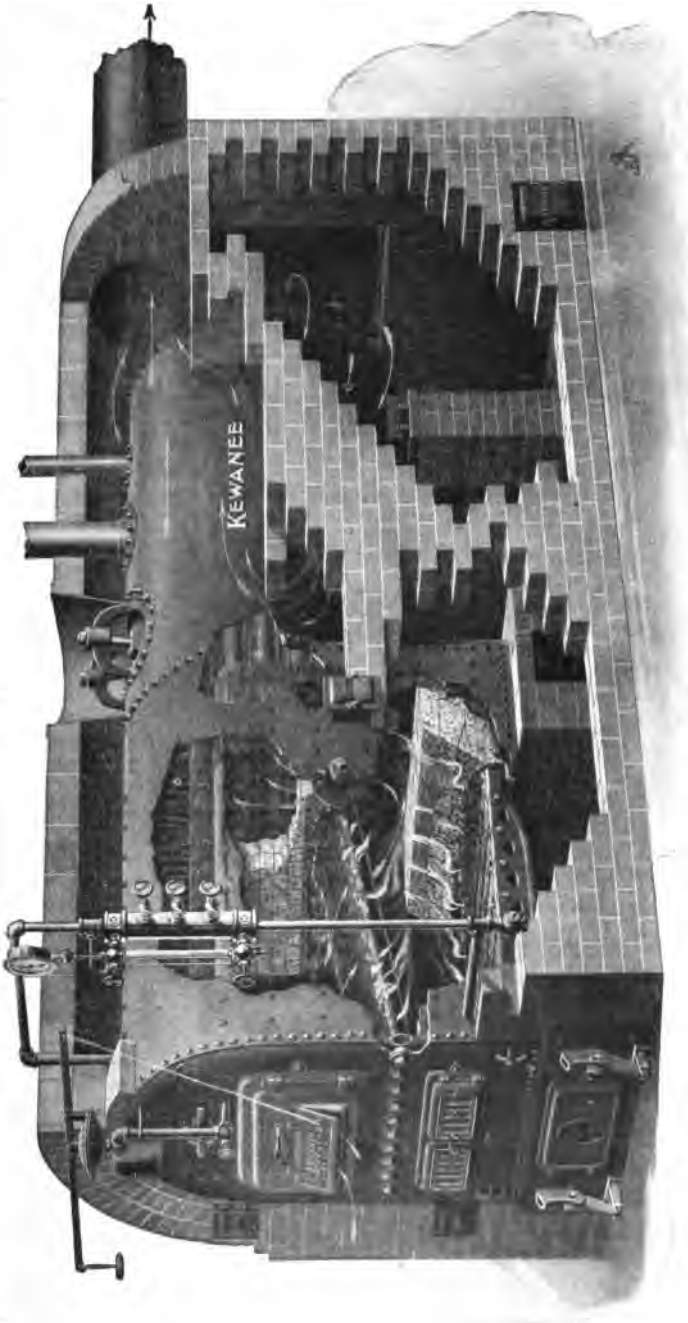


Fig. 6. Sectional View of Smokeless Fire-Box Boiler—Bricket Type, Showing Arrangement of Double Grates
Courtesy of Kewanee Boiler Company, Kewanee, Illinois

ordinary boiler and care should be taken to obtain a stack of good capacity. The manufacturers of these boilers publish in their catalogs the size of stack required. Fig. 6 shows a steel fire-box down-draft boiler.

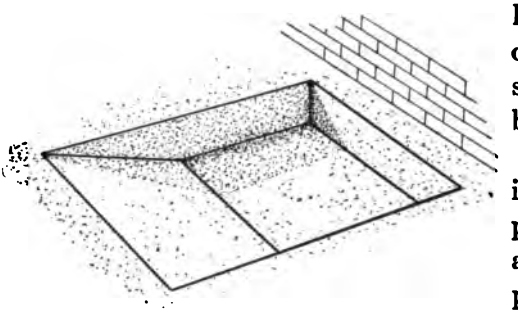


Fig. 7. Pit for Collection of Hot Ashes

Coke Boilers. Coke is a popular fuel in some parts of the country; and certain makers are putting out specially designed boilers for this service, having a very deep fire-box.

Ash Pits. The ash-pits under most boilers are rather shallow; therefore it is a good plan to excavate and build a pit not less than 4 to 6 inches below the floor, to give additional space for the collection of hot ashes, thus avoiding the burning-out of grates. Such pits should be built preferably of concrete as shown in Fig. 7.

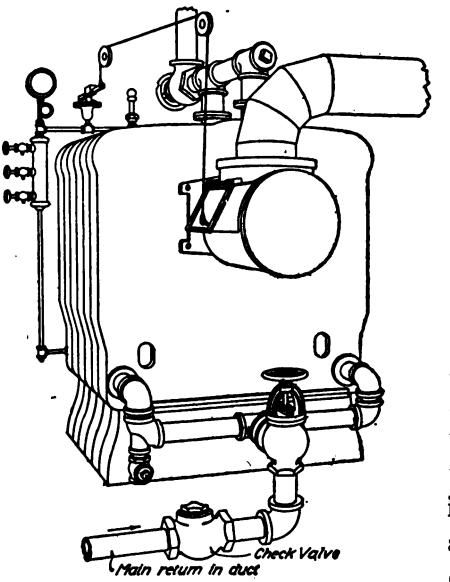


Fig. 8. Typical Arrangement of Return, Showing Check Valve

Boiler Connections. Small jobs frequently have no stop valves at the boiler. In the case of larger ones, or where there are two boilers, valves in the supply mains must always be accompanied with check valves in the returns; otherwise, in case a stop valve in the main steam line is closed, the water will be backed out of the main returns at the boiler, by the pressure. Should the water partially leave the boiler in this manner and then suddenly return, the water coming in contact with the heated sections will crack them.

A stop valve should be placed between the boiler and the check valve in the return. A typical arrangement of return, etc., is shown

in Fig. 8. It is convenient to have an independent drain connection from the returns to provide for drawing off the water in the system without emptying the water from the boiler. The latter, of course, has its independent blow-off cock. The water supply to the boiler should be controlled by a lock-shield valve or a cock that cannot be tampered with by any person not in charge. Boilers having eight sections or more, as a rule, have two or more steam outlets, thus reducing the likelihood of the boiler priming or making wet steam, since, with a single outlet, the velocity of steam through it may be so great that the water is picked up and carried into the piping system.

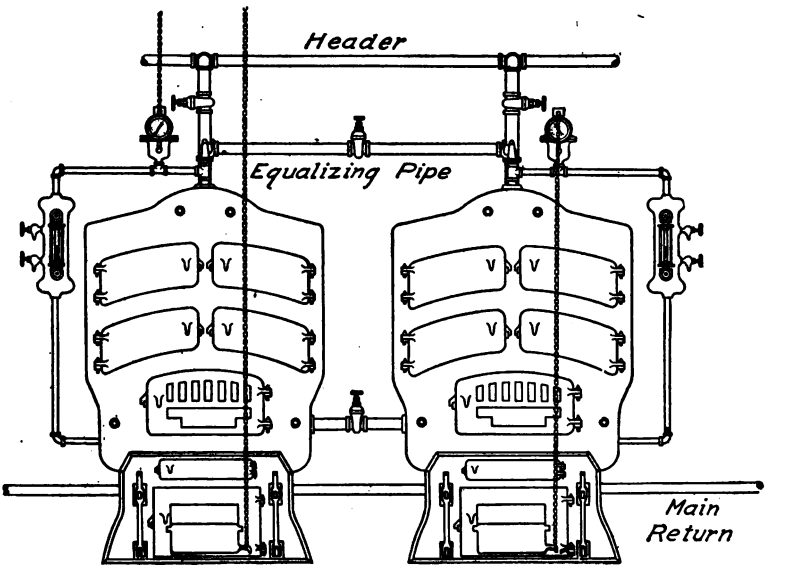


Fig. 9. Method of Connecting Two Boilers.

When two boilers are to be connected, especial care must be taken to make them maintain an even water line when working together. Fig. 9 shows a method of making these connections that is simple and effective. The valved connection between the two boilers, below the water, gives free communication between them, making them work as one and preventing a difference in the water level in the two boilers. The equalizing pipe is often omitted, the header being made about twice the diameter of the pipes leading to it from the boilers.

The returns are connected with the twin boilers practically as

shown in Fig. 8, the check valve being placed between the stop valve of each boiler and the main return.

Boiler Fittings or Trimmings. It is important to have a reliable safety-valve, preferably one of the "pop" type specially designed for steam heating systems.

The damper regulators used are of the ordinary diaphragm pattern, and should be connected by chains with both the lower draft door below the grate, and with the cold-air check in the smoke connection.

The steam gauge with siphon, the water column, water gauge, gauge cocks, etc., require no special description.

Capacity of Boilers. Boiler capacities are commonly expressed in the number of square feet of direct radiating surface they will supply without undue forcing. Mains and risers should, of course, be added to the actual amount of surface in the radiators and coils. Even if the pipes are covered, a small allowance should be added to the combined surface of the radiators. Not less than 50 per cent, and preferably 60 per cent, must be added to indirect radiation, to reduce it to equivalent direct radiation; and not less than 25 to 30 per cent to direct-indirect radiation, to get its equivalent in direct surface. Another point to be kept in mind in selecting a boiler for heating rooms to be kept at different temperatures, is that more heat is given off per square foot of radiation in a room at 50°, for example, than in a room kept at 70°, the amount given off being approximately proportional to the difference in temperature between the steam and the air. With steam at, say, 220°, corresponding to a trifle over 2 pounds' pressure, the difference, in the case assumed, would be $220° - 50° = 170°$, and $220° - 70° = 150°$. That is, the actual amount of radiation in the rooms to be kept at 50° should be multiplied by $\frac{170}{150}$ to ascertain the amount of radiation in a 70° room that would give off the same amount of heat.

It is common practice to allow roughly for the loss of heat from uncovered mains, branches, and risers, by adding about 25 per cent to the actual direct radiating surface in radiators and coils.

Example. What should be the capacity of a boiler to supply steam to 1,000 square feet of direct radiation in a room to be kept at 70°, to 800 square feet of indirect radiation; and to 1,500 square feet of direct radiation, in rooms to be kept at 50° F.?

Direct radiation	1,000 sq. ft.
Equivalent in direct radiation of 800 sq. ft. of indirect = 800 × 1½ =	1,200 " "
Equivalent in direct radiation, in rooms at 70°, of 1,500 sq. ft. in rooms at 50° = 1⅛ × 1,500 =	1,700 " "
Total equivalent D. R. S. (direct radiating surface) exposed in 70° air =	3,900 sq. ft.
Add 25 per cent of actual surface to allow approximately for piping =	825 " "
Total equivalent D. R. S., or Boiler Rating =	4,725 sq. ft.

Grate Surface and Heating Capacity. It is advisable always to check the catalogue ratings of boilers as follows, when selecting one for a given service:

Suppose the Direct Radiating Surface, including piping, is 3,000 square feet. One square foot, it may be assumed, will give off about 250 heat units in one hour—a *heat unit* being the amount of heat necessary to raise the temperature of 1 pound of water 1 degree Fahrenheit. A pound of coal may safely be counted on to give off to the water in the boiler 8,000 heat units. Now, 3,000 sq. ft. × 250 heat units ÷ 8,000 heat units, gives the amount of coal burned per hour; and this, divided by the square feet of grate, gives the rate of combustion per square foot per hour. Suppose in this case, the grate has an area of 15 sq. ft.; then $\frac{3000 \times 250}{8000 \times 15} = 6.25$ pounds coal burned per square foot of grate surface per hour. This is not a high rate for boilers of this size, though for ordinary house-heating boilers the rate should not exceed 5 pounds; and for small heaters having 2 to 4 square feet of grate, the rate should be as low as 3 to 4 pounds per square foot of grate per hour. Otherwise, more frequent attention will be required than it is convenient to give to the operation of such small boilers. This is where depth of fire-box plays an important part, for, with a shallow fire, the coal quickly burns through, necessitating frequent firing.

Coal Consumption. For house-heating boilers a fair maximum rate of combustion is 5 pounds per square foot of grate per hour. In many residences it is the custom to bank the fire at night, when the rate will fall to, say, 1 pound. In cold weather, then, one square foot of grate would burn 5 pounds of coal for each of 16 hours, and 1 pound during each of the remaining 8 hours, a total of 80 + 8 = 88 pounds.

In many sections of the country, the average outside temperature during the heating season is about 40°; and since the heat required is proportional to the difference in temperature between indoors and outside, the average coal consumption would be only $\frac{70° - 40°}{70° - 0°} = \frac{3}{7}$ of the maximum in zero weather.

With a heating season of 200 days, the coal burned on one square foot of grate would be $200 \times \frac{3}{7} \times 88 = 7{,}600$ pounds in round numbers, corresponding to an average rate throughout the season of $\frac{7{,}600 \text{ pounds}}{200 \text{ days} \times 24 \text{ hrs.}} = 1.6$ pounds approximately.

A method of approximating the coal consumption for a given amount of radiating surface, designed to maintain a constant temperature in rooms of 70° day and night, would be to multiply the surface (which, for example, take at 1,000 square feet, including allowance for mains) by 250 heat units—the amount given off by a square foot per hour—and then multiply the product by $\frac{3}{7}$, as explained above, to allow for average conditions. This gives $1{,}000 \times 250 \times \frac{3}{7}$, which, divided by 8,000 heat units per pound of coal, gives the weight of coal required per hour; and this, multiplied by the hours per season, gives the total consumption.

Non-Conducting Coverings. It is customary to cover cast-iron sectional boilers with non-conducting material composed as a rule chiefly of asbestos or magnesia applied in a coating 1½ to 2 inches thick, the exterior being finished hard and smooth.

Exposed basement piping in first-class work is covered with sectional covering ¾ inch to 1 inch thick, according to the character of the work.

The loss of heat through fairly good coverings, is not far from 20 per cent of the loss from a bare pipe, which, with low-pressure steam, is approximately 2 heat units per square foot per hour for each degree difference in temperature between the steam and the surrounding air.

STEAM RADIATORS AND COILS

Direct Radiators. The commonest forms of radiators to-day are the cast iron vertical loop varieties, types of which are shown in Figs. 2 and 13 in Part I (Heating and Ventilation). These are

made up with slip-nipple or screw-nipple connections, the standard height being about 36 to 38 inches.

It is, of course, advisable to use radiators of standard height when possible, since they are cheaper than the lower radiators, which must

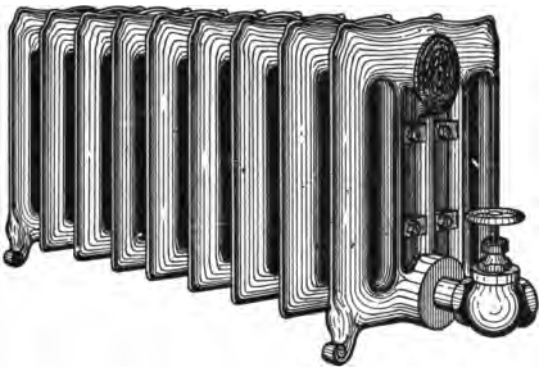


Fig. 10. Low Radiator to be Placed Below Window Sill.

be used when placed below window sills (see Fig. 10). Single-column radiators are more effective than those having a greater number of vertical loops, since in the latter the air flow is retarded and the outer loops cut off the radiant heat from the inner ones. Radiators with four or more columns are generally used where the length of the space in which they must be placed is limited.

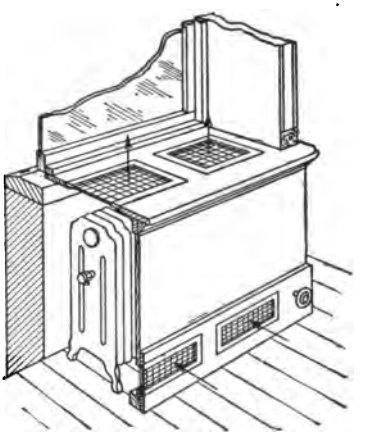


Fig. 11. Concealed Radiator with Register Face.

Wall radiators (see Fig. 4, Part I, Heating and Ventilation) have become very popular because of their neat appearance and the small distance they project into the room. They are very effective heaters, and, although more expensive than certain other types of cast-iron radiators, less surface is required, which tends to offset the increased cost. These radiators are made up in such a variety of forms that they can be adapted to almost any location.

Concealed Radiators. A favorite method of concealing radiators

is to place them below window-sills, with a grating or register face in front of and above them, as shown in Fig. 11. By this arrangement, the radiant heat is to a great extent cut off. The gratings must have ample area to permit the free circulation of air, and should have not

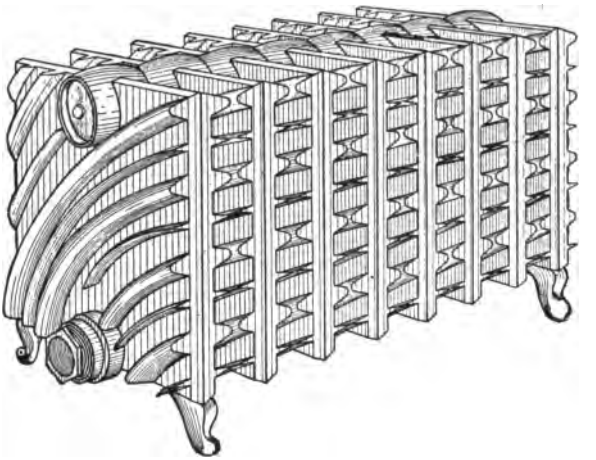


Fig. 12. Radiator for Use without Gratings.

less than 2 or 2½ square inches of free area to each square foot of radiating surface, for inlets and outlets respectively. It is advisable to increase these allowances when possible.

The same rule applies to radiators placed below seats. A radia-

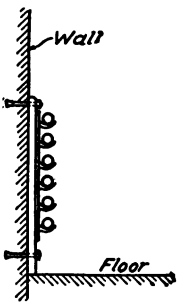


Fig. 13. Hook Plates.

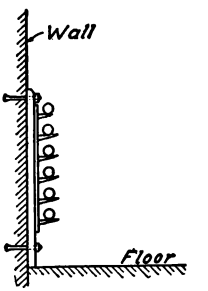


Fig. 14. Expansion Plates.

tor designed specially for this purpose, for use without gratings, is shown in Fig. 12.

Wall Coils. An ordinary wall coil or manifold coil, made up generally of 1¼-inch pipe, with branch tees or manifolds, is illustrated

in Fig. 39, Part I (Heating and Ventilation). The long runs of such coils rest on hook plates (Fig. 13); the short pipes near the corner, on expansion plates (Fig. 14), on which the pipes are free to move when the long pipes expand. Such coils are very effective when placed below the windows of a factory, in which class of buildings they find their widest application.

Miter Coils. Miter coils, as shown in Fig. 15, are used for overhead heating, the coils being suspended about 8 to 10 feet from the floor, and 3 to 4 feet from the walls. A good type of hanger is shown in Fig. 16. The same type of coil, when placed alongside a wall, is known in certain sections as a *harp* coil (see Fig. 17), and may be used where long runs must be made along a wall, but where it is impossible to install the type of coil shown in Fig. 39, Part I (Heating and Ventilation), owing to doorways or other obstructions. Two harp coils could be used along a wall, for example, avoiding a doorway; and the expansion of the pipes would be provided for by the short vertical lines.

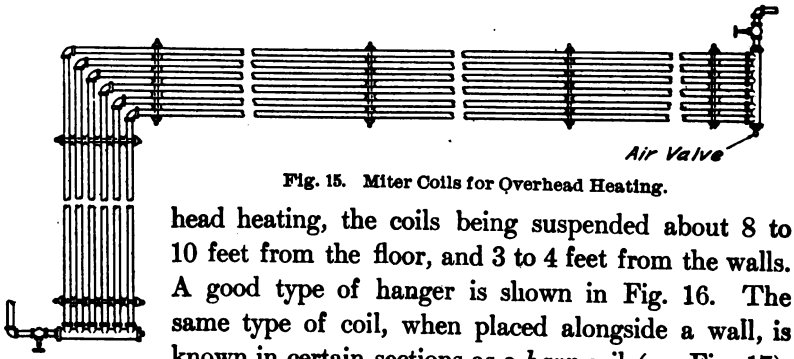


Fig. 15. Miter Coils for Overhead Heating.

Return-Bend Coils. Return-bend coils, known in some parts of the country as *trombone* coils, are shown in Fig. 40, Part I (Heating and Ventilation). These are suitable only for rather short runs, since the steam must pass through the several horizontal pipes successively, and, if the radiating surface is greater than the capacity of the upper line of pipe to supply it properly, the steam is condensed before reaching the lower lines. With the harp or other coils having headers or branch tees, sufficient steam can enter to fill all the pipes at once, passing through the parallel lines at the same time.

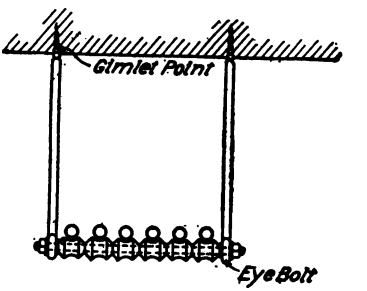


Fig. 16. An Approved Type of Hanger.

Direct-Indirect Radiators. A *direct-indirect* radiator is shown in Fig. 18. The air enters through a louvered or slatted wall opening with screen. Provision is made to shut this off and admit air simultaneously from the room, making the radiator essentially a direct radiator when the cold air is shut off. The best location for the cold-air opening is probably just below the sills, the wall boxes being less conspicuous in this position.

Two forms of indirect radiators are

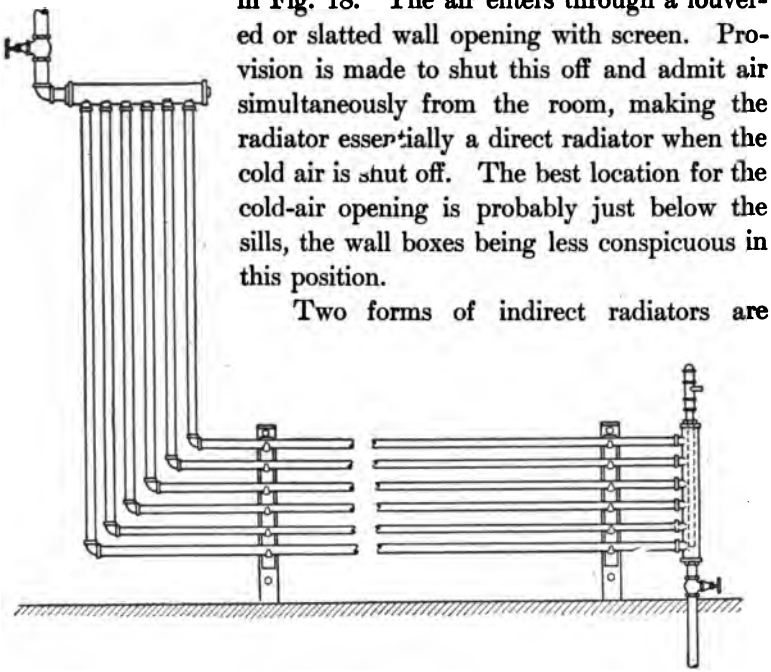


Fig. 17. Harp Coil.

shown in Fig. 7, Part I, and Fig. 3, Part II (Heating and Ventilation), the shallow sections being used largely for house heating, the deep ones for schoolhouse systems. The latter are provided with extra long nipples for spacing the sections about 4 inches on centers, to give a proper passage for a large volume of air.

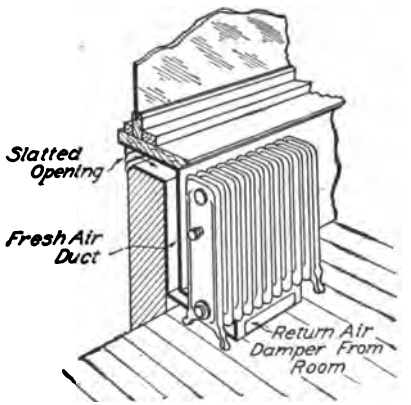


Fig. 18. Direct-Indirect Radiator.

Indirect Radiators. The indirect radiators are enclosed in galvanized-iron casings about 30 inches deep, giving a space of 6 or 8 inches above and below the radiators. The beams over the radiators are commonly covered with rough boards, to which tin or

tin and asbestos is nailed, the casing being flanged at the top and screwed or nailed to these boards.

The casings should be made with corners of a type that will permit the ready removal of the sides in case of repairs being needed; and the bottom of the casing should be provided with a slide for inspection and cleaning. The larger sections, when used for schoolhouse heating, are arranged as shown in Fig. 19, with a mixing damper designed to cause a mingling of the warm and cold air in the flue, the volume discharged being but slightly reduced, with a decrease in temperature due to opening the damper to cold air. The space for the passage of air between the shallow sections containing about 10 square feet each, is about $\frac{1}{3}$ of a foot; the space between the sections of the deep pattern is not far from $\frac{1}{2}$ a foot when the sections are properly spaced.

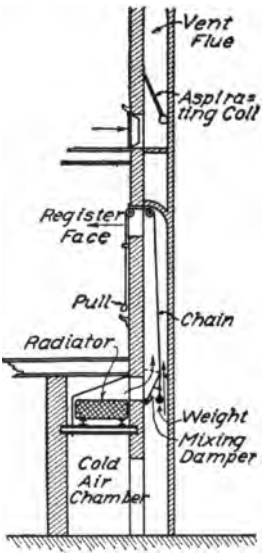


Fig. 19. Arrangement of Casings for Use in Connection with Indirect Radiators.

Heat Given Off by Steam Radiators. Of the heat emitted by direct radiators, approximately one-half is by radiation, the balance by convection or the contact of air. Since practically no heat is radiated from concealed radiators, it is very important that proper provision should be made for the passage of an adequate volume of air over the heating surface.

TABLE I

Heat Units Emitted from Radiators and Coils

Radiation per square foot of radiating surface per hour.—In rooms at 70° F. temperature.—With steam at 3 to 5 pounds' pressure.

Type of Radiator	Heat Units Emitted (Approximate)
Concealed cast-iron direct radiators	175–200
Ordinary cast-iron vertical-section radiators	250
Wall radiators	300
Pipe coils on walls	325
Pipe coils overhead (pipes side by side)	350
Ordinary cast-iron extended-surface indirect radiators (air admitted from outdoors)	400

Wall radiators and coils give off more heat under the same conditions than is emitted by ordinary vertical cast-iron radiators.

Much might be said regarding the efficiency of radiators due to their height, form, and arrangement. For the purposes of this course, however, only fair average values will be given, as set forth in Table I, a discussion of radiator tests, etc., being omitted to avoid unnecessary detail.

STEAM PIPING

Size of Main for Circuit System. Since the main of a circuit system, as described in Part I (Heating and Ventilation), must carry both steam and water of condensation, it should be made considerably larger in proportion to the surface supplied than mains which are dripped at intervals or which carry only the condensation from the main itself.

Sizes, ample for circuit mains of ordinary length, are indicated in the accompanying table:

TABLE II

Sizes of Circuit Mains

Diameter of Circuit Main	Direct Radiating Surface
2 inches	200 sq. ft.
2½ "	350 " "
3 "	600 " "
3½ "	900 " "
4 "	1,200 " "
4½ "	1,700 " "
5 "	2,100 " "
6 "	3,000 " "

Dry Return System. In many cases it is desirable to run the supply and return mains overhead. Such systems contain less water than wet return systems, and are therefore more susceptible to changes in the fire, because of the smaller quantity of water in the apparatus. The return mains must be made larger than when they are placed below the water line, since they are filled with steam, except the space occupied by the return water running along the bottom. The pipes should have a greater pitch than wet returns.

With dry returns, if certain supply risers are of inadequate size, steam is apt to back up into the radiator through the dry returns and to cause a holding-back of the water in the radiators. To prevent this,

check valves are sometimes introduced in the branch returns. If the piping is properly proportioned, however, this is unnecessary. Siphon drips are frequently used, as explained in Part I (Heating and Ventilation).

Wet Return Systems. This system, illustrated in Fig. 20, provides for water sealing all returns and drips, and avoids the backing-up action mentioned above. Suppose, for example, the pressure in one of the vertical returns is ½ pound less than in the others; then, since a column of water 2.3 feet high corresponds to 1 pound pressure, the water will back up this particular return about 1.15 feet higher than in the others and thus equalize the difference in pressure. Where the mains must be long, the wet return system affords the opportunity to rise and drip the supply main as often as necessary; whereas, with the dry return system, the main and return have a gradual pitch from start to finish. This often brings the return so low as to interfere with head room. With the wet return system the return may be dropped below the floor line at doorways without interfering with the circulation. The sizes of wet returns may be made considerably smaller than dry returns for a given radiating surface, as shown in Table III.

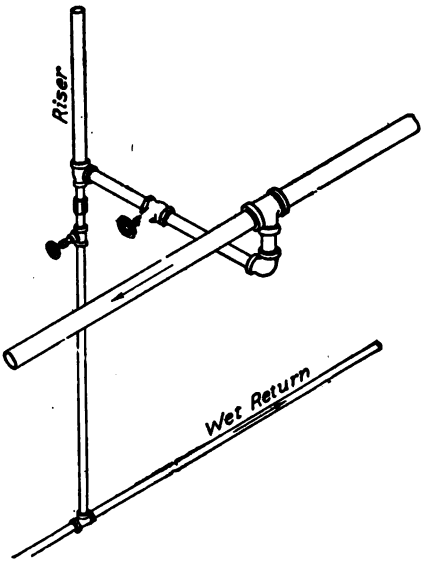


Fig. 20. Wet Return System.

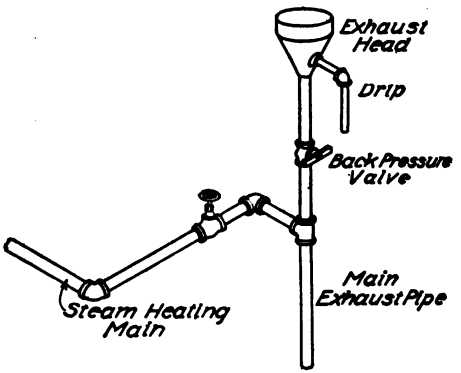


Fig. 21. Overhead Feed System.

Overhead Feed System. The overhead feed system (see Fig. 21)

is most commonly used in connection with exhaust steam plants, since in such systems the exhaust pipe from the engines must be carried to the roof, and the steam supply to the building may conveniently be taken from a tee near the upper end of this pipe. The main should be pitched down, and outlets taken from the bottom, to drain the condensation through the risers (see Fig. 22). With this system the water of condensation always flows in the same direction as the steam; hence the horizontal pipes and the risers may be made somewhat smaller than in up-feed systems.

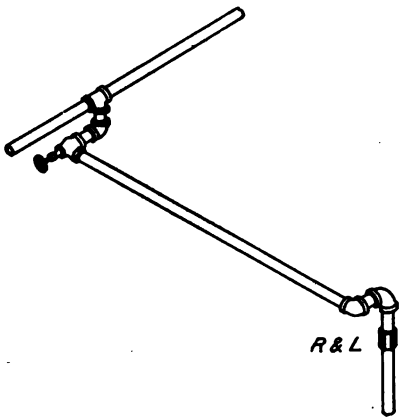


Fig. 22. Outlet Taken from Bottom of Main.

This system has the advantage of placing the big pipes in the attic, where their heating effect is less objectionable than in the basement. As the pipes gradually decrease in size from top to bottom, this gives small pipes on the lower floors, which in modern buildings generally contain a few large rooms and little space for concealing pipes. It is frequently advisable to combine with this system the up-feed method of heating the first floor, which is generally high-studded and requires a large amount of radiation. Relieving the down-feed system of this load means smaller risers throughout the building, which, in the modern sky-scraper, results in a saving that more than offsets the cost of the separate up-feed system for the lower floor. Another reason why it is advisable to put the lower floor on a separate system, is that the steam is dry, whereas the steam from an overhead system becomes pretty wet from condensation by the time it reaches the lower floor.

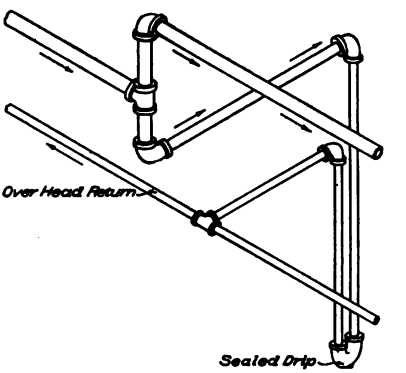


Fig. 23. Siphon Trap.

One-Pipe System. The one-pipe up-feed system is most commonly used in connection with relatively small heating plants. It has the advantage of simplicity, there being but a single valve to operate. In tall buildings with the up-feed system, the risers must be objectionably large to provide for the passage of steam up, and water of condensation down, the same pipe. With the overhead system, the risers may be made considerably smaller, since the water is not hindered in its passage by a flow of steam in the opposite direction. With this one-pipe system, the radiator connections should be short and pitched downward toward the risers to avoid pockets. When used in high buildings with the overhead system, the lower portion of the risers must be liberally proportioned, otherwise the steam will become too wet.

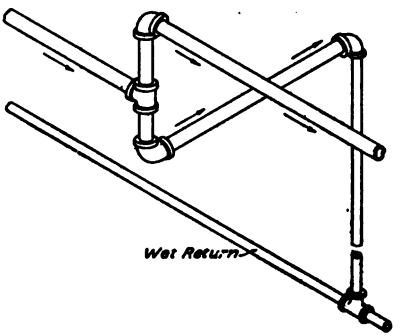


Fig. 24. Arrangement to Rise and Drip in Mains at Intervals.

The Two-Pipe System. This system is commonly used where the radiator connections must be long and where it would be impossible to secure a proper pitch to insure good drainage with one-pipe radiator connections. Coils are nearly always made up with two-pipe connections. In high buildings, where a large amount of radiation must be carried by each riser, they may be made smaller if two-pipe connections are made with the radiators. This is often a decided advantage, especially if the risers are to be concealed.

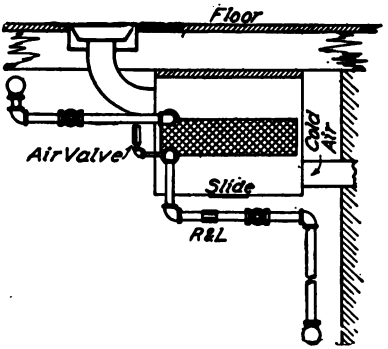


Fig. 25. Arrangement for Draining with Indirect System.

Draining Mains and Risers. With long mains, it frequently is the case that if given a continuous pitch they would be too low at the extreme ends; and it is therefore customary to rise and drip at intervals, as shown in Figs. 23 and 24.

The *siphon trap* (Fig. 23) prevents a greater pressure being introduced along the overhead return than occurs at the extreme end, since any excess in pressure at an intermediate point merely forces down the water in the inlet leg of the siphon trap to a point where the difference in pressure in the two mains is equalized by the higher level of water maintained in the outlet pipe of the syphon trap.

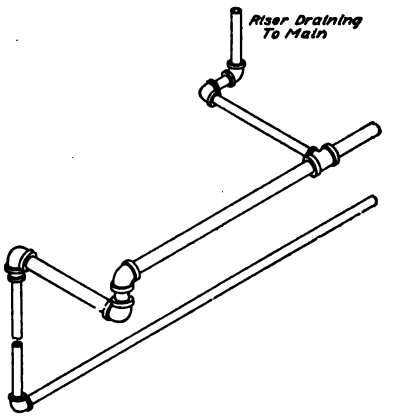


Fig. 26. Risers Drained to Main and Main Drained at End.

With indirect systems, the mains are frequently drained through the benches or stacks of radiators, the connections being taken from the bottom of the main. It is assumed that all the indirects will not be shut off at the same time (see Fig. 25).

Mains and risers are commonly drained as shown in Fig. 20, connections being taken from the bottom of the main and the heel of the riser. Risers are not infrequently drained to the main, which in turn is drained at the end (see Fig. 26). This arrangement requires less fitting than when the

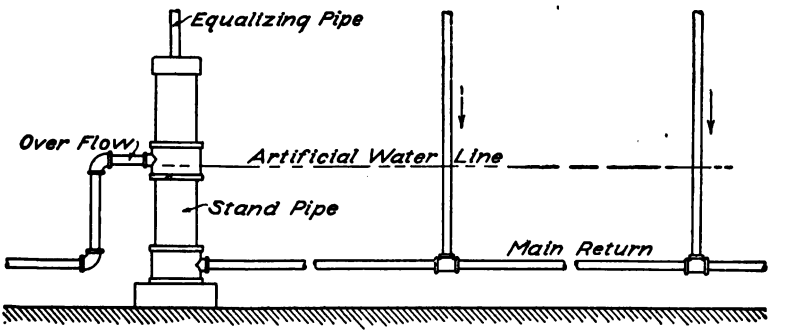


Fig. 27. Showing Artificial Water Line.

risers are relieved at the base, as shown in Fig. 20. If the mains are long, they should be dripped at intervals of 50 to 75 feet.

Overhead-feed mains on a down-feed system are nearly always dripped from the bottom to the various risers, as previously stated.

Artificial Water Line. It is sometimes necessary, when a boiler

is set very low with reference to the returns, and it is desired to use a wet return system, to seal the relief pipes by means of an artificial water line established as shown in Fig. 27. The equalizing pipe is to be connected with a steam main.

When the discharge from the system leads to an open return, a trap must be used. One of the type shown in Fig. 28, arranged with an equalizing pipe and set at the proper level, will hold the water line in the system, no standpipe being required.

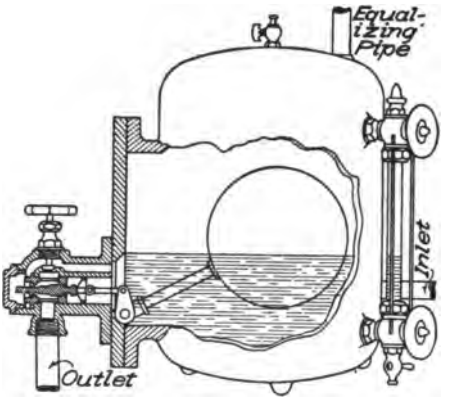


Fig. 28. Water Line Trap with Equalizing Pipe.

Pipe Sizes.—Mains. The capacities of pipes to supply heating surface increase more rapidly than their sectional areas; that is, a 6-inch pipe, with about four times the area of a 3-inch pipe, will supply nearly six times as much surface.

Table III shows the amounts of radiating surface in gravity-return systems which main pipes 100 feet long, of different diameters, may be safely counted on to supply with low-pressure steam (say, 3 to 5 lbs.).

In case the radiating surface is located some distance above the water line in the boiler, the carrying capacity of the pipes may be increased as much as 50 per cent, owing to the greater drop in pressure that may be allowed without interfering with the return of water to the boiler.

Mains are frequently made much larger than necessary, simply because the fact has been overlooked that the radiators are located well above the boiler, and that a drop in pressure between the boiler and the end of the main of $\frac{1}{4}$ lb., or even more, would be permissible.

The greater the drop in pressure allowed the smaller may be the pipe for a given capacity.

Pipe Sizes.—One-Pipe Risers. Riser capacities are given in Table IV.

TABLE III

Capacity of Supply Mains, Gravity Return System, and Size of Dry and Wet Returns

Mains 100 ft. long —Steam at low pressure (3 to 5 lbs.).

Diameter of Supply Pipe	Capacity in Direct Radiating Surface	Diameter of Dry Return	Diameter of Wet Return
1 inch	55 sq. ft.	¾ inch	¾ inch
1¼ inches	115 " "	1 "	1 "
1½ "	175 " "	1¼ inches	1¼ inches
2 "	325 " "	1½ "	1¼ "
2½ "	570 " "	2 "	1½ "
3 "	1,000 " "	2½ "	2 "
3½ "	1,480 " "	3 "	2½ "
4 "	2,000 " "	3 "	2½ "
4½ "	2,770 " "	3 "	2½ "
5 "	3,500 " "	3½-4 "	3 "
6 "	5,700 " "	4-5 "	3½-4 "
7 "	8,800 " "	4-5 "	4 "
8 "	12,000 " "	4-5 "	4 "
10 "	20,000 " "	5-6 "	4 "
12 "	33,000 " "	5-6 "	4-5 "

For lengths greater than 100 ft. and for same drop in pressure as for 100 ft., multiply the above figures by 0.8 for 150 ft.; 0.7 for 200 ft.; 0.6 for 300 ft.; 0.5 for 400 ft.; 0.4 for 600 ft.; and 0.3 for 1,000 ft. When the pressure at the supply end of the pipe can be increased for long runs so that the drop in pressure for each 100 ft. can be the same, then the figures in the table can be used for long runs.

TABLE IV

Capacities of One-Pipe Risers

Size of Pipe	Capacity, Up-Feed	Capacity, Down-Feed
1 inch	30 sq. ft.	60 sq. ft.
1¼ inches	60 " "	110 " "
1½ "	120 " "	160 " "
2 "	200 " "	260 " "
2½ "	300 " "	400 " "
3 "	450 " "	600 " "
3½ "	620 " "	800 " "
4 "	800 " "	1,000 " "

The capacities of the 1-inch and 1¼-inch pipes for up-feed are somewhat greater than those stated; but they are given as above, since these figures correspond closely to standard radiator tapping, and it is advisable to make the pipes of the same size as the tapped openings.

In high buildings with the down-feed system, the lower half of the risers should be based on not much more than half the capacities stated in the right-hand column, in order that the pipes may be of ample size to carry off the great amount of condensation from the radiators above, without making the steam too wet for use in the radiators below. The pipe to the lowest radiator connection should be not less than 2-inch.

Pipe Sizes.—Two-Pipe Risers. With the two-pipe system, the capacity of the risers is of course, considerably greater than with the one-pipe system, since the condensation is carried off through a separate system of returns.

Table V gives the approximate capacities of risers for the two-pipe system.

TABLE V

Capacities of Two-Pipe Risers

Size, Supply Riser	Capacity, Up-Feed System	Capacity, Down-Feed System	Size, Return Riser
1 inch	50 sq. ft.	55 sq. ft.	¾ inch
1¼ inches	100 " "	115 " "	1 "
1½ "	150 " "	175 " "	1 -1¼ inches
2 "	270 " "	325 " "	1 -1¼ "
2½ "	470 " "	570 " "	1¼-1½ "
3 "	840 " "	1,000 " "	1¼-1½ "
3½ "	1,200 " "	1,480 " "	1½-2 "
4 "	1,600 " "	2,000 " "	1½-2 "

In buildings over six stories high, with the up-feed system, use 10 per cent less surface than stated in the third column, to allow for the increased length and condensation.

Pipe Sizes, Indirect. Supply connections with indirect radiators must be larger for a given surface than for direct radiators. The following table gives ample sizes when the radiators are but little above the water line of the boiler. When this distance is con-

TABLE VI

Sizes of Supply Connections for Indirect Radiators

Diameter of Pipe	Indirect Radiating Surface Supplied
1 inch	40 sq. ft.
1¼ inches	70 " "
1½ "	100 " "
2 "	180 " "
2½ "	330 " "
3 "	600 " "
3½ "	900 " "
4 "	1,200 " "
4½ "	1,600 " "
5 "	2,100 " "
6 "	3,400 " "
7 "	5,400 " "
8 "	7,200 " "

siderable, the pipes may be safely rated to supply one-third more surface; for a greater drop in pressure may be allowed between the

supply and the return mains, and drop in pressure means a greater velocity in the pipes, and consequently a greater flow of steam to the radiators.

Indirect radiators are seldom tapped larger than 2 inches; therefore radiators that require larger connections should be subdivided in groups.

STEAM PRESSURES AND TEMPERATURES

Steam pressures and temperatures have a certain definite relation to each other, the temperature increasing with the pressure, but not as rapidly for a given increase with high-pressure as with low-pressure steam. For example, with an increase in pressure from 10 pounds to 20 pounds, the temperature rises about 19° F.; whereas with an increase of 10 pounds from 90 to 100 pounds the temperature increases

TABLE VII

Temperature of Steam at Various Pressures

Vacuum (in Inches of Mercury)	Temp. °F.	Gauge Pressure (lbs. per sq. in.)	Temp. °F.
0	212.1	0	212
5	203.1	1.3	216.3
10	192.4	2.3	219.4
12	187.5	3.3	222.4
14	182.1	4.3	225.2
16	176.0	5.3	227.9
18	169.4	10.3	240.0
20	161.5	20.3	259.2
22	152.3	30.3	274.3
24	147.9	40.3	286.9
26	125.6	50.3	297.8
28	101.4	60.3	307.4
		70.3	316.0
		80.3	323.9
		90.3	331.1
		100.3	337.8
		150.3	365.7
		200.3	387.7

only about 7° F. From atmospheric pressure to 10 pounds' gauge pressure, the increase in temperature is nearly 28° F; a slight difference in the pressure in radiators making a marked difference in their temperature.

In the case of a *partial vacuum*, so called—expressed generally

in inches of mercury—the decrease in temperature as a condition of perfect vacuum is approached is very marked, as shown in table VII, which gives also steam temperatures corresponding to various pressures. The latter are given in each case $\frac{3}{10}$ of a pound in excess of the gauge pressure, as practically all tables of the properties of steam give the absolute pressure—that is, the pressure above a vacuum—the absolute pressure corresponding to 5.3 pounds' gauge pressure, for example, being 20 pounds absolute.

The atmospheric pressure at sea-level is practically 14.7 pounds absolute, and the boiling point of water is 212°. As the pressure decreases, due to altitude or to the removal of air from a vessel by artificial means, the boiling point falls.

EXPANSION

Amount of Expansion. An allowance of $\frac{8}{1000}$ of an inch per 100 feet of pipe for each degree rise in temperature, is a fair allowance in computing the amount of expansion that will take place in a line of pipe.

One must assume the temperature at which the pipe will be put up—say anywhere from 0° to 40° in an unfinished building in winter—and, knowing the pressure to be carried, look up in a table of the properties of saturated steam the temperature corresponding. See table VII.

Example. Find the expansion that will take place in a line 100 feet long put up in 30-degree weather, when it is filled with steam at 80 pounds' pressure. The temperature corresponding to 80 pounds'

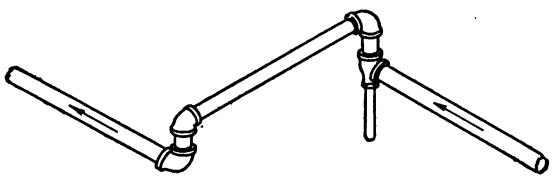


Fig. 29. Offset and Swivels.

steam pressure is 324°; the increase from 30° is 294°, which multiplied by $\frac{8}{1000}$ gives $2\frac{35}{100}$ inches expansion, or, expressed in decimals, 2.35 inches.

In low-pressure work 100 feet of pipe heated from 30° to 230° will expand about 1.6 inches.

Provision for Expansion. The expansion of mains can generally be provided for by offsets and swivels, as shown in Fig. 29. All that is necessary is to have the two vertical nipples placed far enough apart, as determined by the length of the horizontal offset, to permit the expansion to take place without too much turning on the threads. The less the turn, the less will be the likelihood of leakage. The shorter the offsets, the greater the number that must be used.

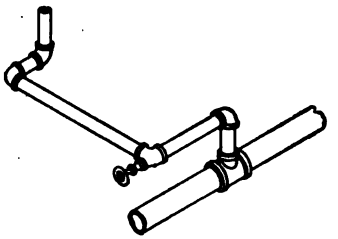


Fig. 30. Swing to Allow for Expansion of Risers.

A pretty conservative rule would be to allow 4 feet of offset to each inch of expansion to be taken up on the line. In the case of underground work a good deal of the expansion can be taken up where pipes enter buildings by the same kind of swings as shown in Fig. 29, making them longer and thus reducing the number of expansion joints or offsets in the tunnel or duct.

Expansion of Risers. In providing for the expansion of risers, considerable skill must be used, especially in tall buildings. In buildings of not over 6 to 8 stories, or possibly 10 floors at the outside, if they are not high-studded, the expansion may all be taken up in the basement, using swings like those shown in Fig. 30, similar swings being used in the attic also if the overhead-feed system is used, the connections being taken from the bottom of the main, as previously stated.

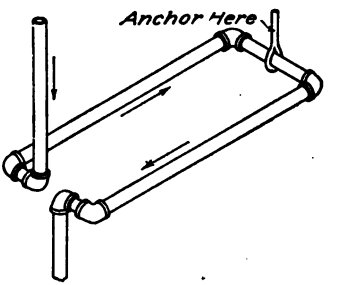


Fig. 31. Expansion Joints. Offsets Nearly Horizontal.

In higher buildings than those mentioned, either slip-pattern expansion joints or swivels made up of pipe and fittings are commonly used. One of these to every six to eight floors is generally considered sufficient, depending on the length and arrangement of the radiator connections. One must be sure the pipes above and below slip joints are in proper alignment; otherwise, binding and leakage will occur. If the risers are concealed, such joints must be made accessible through proper openings in the walls, as the packing will have to be taken up from time to time and replaced.

Expansion joints made up of pipes are illustrated in Fig. 31. Such joints are unsightly if exposed; but they may generally be concealed either in specially provided pockets in the floor or in spaces furred down below the ceilings and near the walls.

When expansion joints are used, the risers should be anchored about midway between them. These anchors consist merely of clamps around the pipes fastened to the beams, one type being shown in Fig. 32.

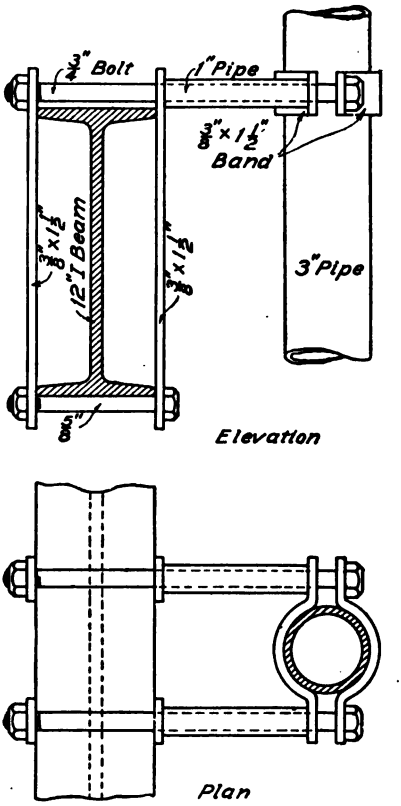


Fig. 32. Anchor for Riser.

Radiator Connections. Considerable ingenuity is exhibited by good fitters in arranging radiator connections. One should always study the end sought, and then provide the necessary means to secure that end. For example, on a floor at which the riser is anchored, almost any sort of radiator connection will answer, since expansion need not be provided for.

Where expansion takes place, swivels must be provided in the radiator connections, to allow for same. Fig. 33 shows a convenient way of taking off radiator connections from risers, any expansion

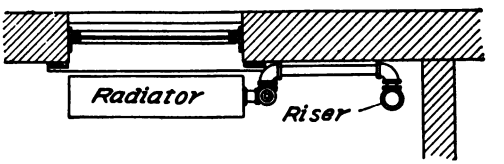


Fig. 33. Radiator Connections from Riser.

being taken up by the turning of the horizontal connection in the parallel nipples. The connection should of course pitch back toward

the riser, to drain freely. Where the expansion is considerable, this is difficult to accomplish unless the radiator is slightly raised.

When risers must be located along the same wall as that on which the radiator is placed, the swivels may be arranged as shown in Fig. 34.

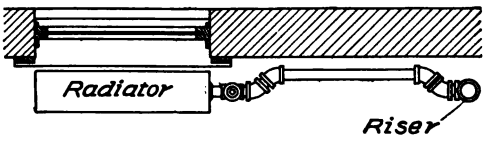


Fig. 34. Arrangement of Swivels when Risers are Located on the Same Wall as Radiator.

Radiators on the first floor have their connections made by angle valves with the pipes in the basement, to avoid running along the base-board. It is well to take the branch to the first-floor radiators from riser connections in the basement, rather than to cut into the mains for these branches. See Fig. 35.

COMPUTING RADIATION

Computing Direct Radiation. It is a perfectly simple matter to compute the amount of radiation required to heat a room, by finding the probable loss of heat per hour, and dividing this by the heat given off by a square foot of radiating surface in the same time.

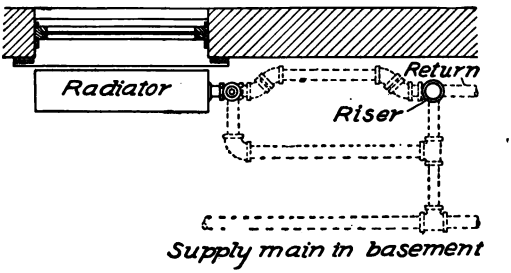


Fig. 35. Branch from Riser Connection in Basement.

Numerous tests have shown that an ordinary cast-iron radiator gives off approximately 1.6 heat units per hour per degree difference in temperature between the steam and the surrounding air. With low-pressure heating a square foot of direct radiation is commonly rated at about 250 H. U. Glass transmits about 85 heat units per square foot per hour, with 70° inside and 0° out; and walls of ordinary thickness may be reckoned as transmitting one-fourth as much heat.

The heat losses stated should be increased about 25 per cent for a north or west exposure, and about 15 per cent for an easterly exposure.

An allowance should be made for reheating rooms that are allowed to cool down slightly at night. This may be done most con-

veniently by adding to the loss of heat through walls and glass a number of heat units equal to 0.6 of the cubic contents of a room with two exposures, and 0.3 for a room with a single exposure.

To illustrate the method the following examples are given:

Suppose we have a room 16 feet square and 10 feet high, with two exposed walls facing respectively north and west, each having a window 3 feet 6 inches by 6 feet.

Exposure of room = (16+16)×10 =	320 sq. ft.
Glass surface = 2×21 sq. ft. =	42 " "
Net wall	278 sq. ft.
Equivalent glass surface (E. G. S.) of net wall = 278÷4 = Approx.	70 sq. ft.
Actual glass surface =	42 " "
Total E. G. S. Approx.	112 sq. ft.
Heat transmitted = 112 sq. ft. ×85 heat units ×1.25 factor =	11,900 H. U.
Allowance for reheating = 0.6 × cubic contents of 2,560 cu. ft. =	1,536 H. U.
Total heat loss to be made good by direct radiation	13,436 H. U.

This 13,436 heat units, divided by 250, the amount given off by one square foot of radiation in one hour, = 54 sq. ft. approximately, giving a ratio of 1 sq. ft. of radiating surface to 50 cubic feet of space.

Now take a room with one east exposure, the dimensions being 14 by 14 by 10 feet, with one window 4 by 6 feet.

Exposure =	140 sq. ft.
Glass =	24 " "
Net wall	116 sq. ft.
E. G. S. of net wall = ¼ of same =	29 " "
Add actual glass =	24 " "
Total E. G. S.	53 sq. ft.
Heat loss per hour = 67×85×1.15 =	5,180 H. U.
Add 0.3 of the contents to allow for reheating; 0.3×1,960 =	588 H. U.
Total heat loss	5,768 H. U.

This 5,768 heat units ÷ 250 = 24 sq. ft. radiation required, giving a ratio of 1 to 82 cubic ft.

The following record form will be found advantageous:

1	2	3	4	5	6	7
Room	Exposure	Cubic Contents	Exposed Wall	Glass	Radiation (Computed)	Radiation (Plans)

After computations are made, radiation can be totaled and size of boiler can be determined and noted at bottom of sheet.

The loss of heat through roofs and through ceilings to unheated attic spaces above may be found by dividing the area of the roof by 10, and that of the ceiling by 20, to give the E.G.S. For a well-constructed plank roof, with paper or other material above, a dividing factor of 15 can be used for the roof.

It is hardly necessary, as a rule, to allow for the loss of heat through a first floor to the basement when the latter is well enclosed and contains steam and return mains or is otherwise kept at a moderate temperature.

Computing Direct-Indirect Radiation. The most common method of computing the amount of direct-indirect radiation required, is to ascertain, in the manner described, the direct radiating surface necessary, and add to it approximately 25 per cent; that is, if a direct radiator of 100 square feet were found to be necessary to heat a given room, a direct-indirect radiator of 125 square feet would be required.

Computing Indirect Radiation. To compute the amount of indirect radiation necessary to heat a given room, about the simplest method to grasp is to compute, first, the direct radiation required, as previously explained, and then add 50 per cent to this amount, since it happens that, under average conditions of 70° inside and 0° outside, practically 1½ times as much surface is required to heat a given space with indirect as with direct heating.

When a stated air supply is required, the loss of heat by ventilation must be computed, and a different method followed in ascertaining the amount of indirect radiation required. For example, take a 50-pupil schoolroom with the common compulsory allowance of 30 cubic feet of air per minute per pupil—equal to 1500 cubic feet per minute per room. Each cubic foot escaping up the vent flue at 70° F., when the outside temperature is zero, removes from the room 1¼ heat units; hence the total heat loss by ventilation per hour would be $60 \times 1500 \times 1\frac{1}{4} = 112{,}500$ heat units. A standard schoolroom has about 720 square feet of exposure, of which not far from 180 square feet is glass, leaving a net wall of 540 square feet, which, divided by 4, gives 135 square feet equivalent glass surface. This, added to the actual glass, gives 315 square feet E. G. S., which, in turn, multiplied by 85 heat units × a factor of 1.25 for north or west, gives a total heat loss by transmission of 33,470 heat units approximately.

The combined loss of heat by transmission and ventilation amounts to 145,970 H. U.

With the greater air-flow through indirect heaters used in schools, the heat emitted per square foot per hour should exceed somewhat the amount given off by indirect radiators in residence work—namely, 400 H. U. To be on the safe side, allow 450 H. U. The total heat

loss from the room, divided by this number, gives approximately 300 square feet as the surface required.

DUCTS, FLUES, AND REGISTERS

Areas of Ducts and Flues. The area of the cold-air connections with the benches or stacks of indirect radiators, are generally based on 1 to 1¼ square inches of area to each square foot of surface in the radiators.

The flues to the first floor should have 1½ to 2 square inches area to each square foot of surface; those to the second floor, 1¼ to 1½ square inches; and those to floors above the second, 1 to 1¼ square inches per square foot of radiation.

The sides and back of warm-air flues in exposed walls should be protected from loss of heat by means of a nonconducting covering, preferably ½ inch thick.

Flue Velocities. A fair allowance for flue velocities with indirect steam heating is 275 feet per minute for the first floor, 375 feet for the second, 425 feet for the third, and 475 for the fourth.

Registers. The net area of registers should be 10 to 25 per cent in excess of the area of the flue with which they are connected. The net area of a register is commonly taken as ⅔ the gross area; that is, a 12 by 15-inch register would have a net area of 120 square inches.

Registers in shallow flues must either be of the convex pattern, or be set out on a moulding to avoid having the body project into the flue and cut off a portion of its area.

Aspirating Heaters and Coils. To cause a more rapid flow of air in ventilating flues in mild weather, steam coils or heaters are used. These should be placed as far below the top of the vent flue as possible, for the higher the column of heated air, the greater the chimney effect. The smaller the flue in proportion to the volume of air to be handled, the larger should be the heater. If cast-iron indirect radiators are used, they may be rated to give off about 350 heat units per square foot per hour; coils may be rated to give off nearly double that number of heat units.

To illustrate how to compute the size of coil to be used, assume for example that 1,500 cubic feet per minute are to be removed

through a ventilating flue, the air to be raised 10° in temperature. Then

$$\frac{\text{1,500 cu. ft. per min.} \times \text{60 min. per hour} \times \text{10° rise in temp.}}{\text{55 heat units} \times \text{650 heat units per hour per sq. ft. of coil}} = 25.+ \text{ sq. ft. of coil required.}$$

(The number 55 is the number of cubic feet of air at 70° that 1 heat unit will raise 1° F.)

In order to work out important problems of this nature, it is necessary to consult a table giving flue velocities for different heights and for excesses of temperature of air in the flue over that out of doors. From such a table, knowing the height of the flue, its size, and the volume of air to be moved, it is readily seen how many degrees the air must be heated. The size of coil is then determined as above. The arrangement of an aspirating heater in a flue is shown in Fig. 36.

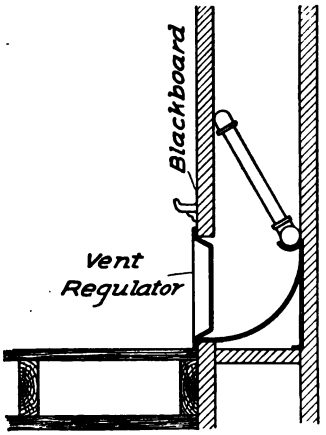


Fig. 36. Aspirating Regulator in Flue.

EXHAUST-STEAM HEATING

Buildings having their own power and lighting plant should be heated by exhaust steam, about 90 per cent of the steam that passes through the engines and pumps being available for this purpose.

A portion of this steam is used for heating the feed-water to the boilers. In a properly arranged system, very little fresh water need be supplied, since the condensation from the radiators, properly purified, is returned to the boilers.

To accomplish this purification, and to rid the steam of oil in order to prevent its coating the pipes and radiators, the steam is passed through a separator attached to the heater when all the steam is allowed to enter it, or through an independent separator when only a portion of the steam passes through the feed-water heater. Only about one-sixth of the exhaust steam in a given plant is required to heat the feed-water that must be supplied to the boilers to take the place of the steam used in the engines, therefore all the exhaust need

not enter the heater for the purpose of keeping up the proper temperature of the feed-water.

A type of heater with a coke fitter is shown in Fig. 37; while Figs. 38 and 39 show two methods of making connections, the first when all

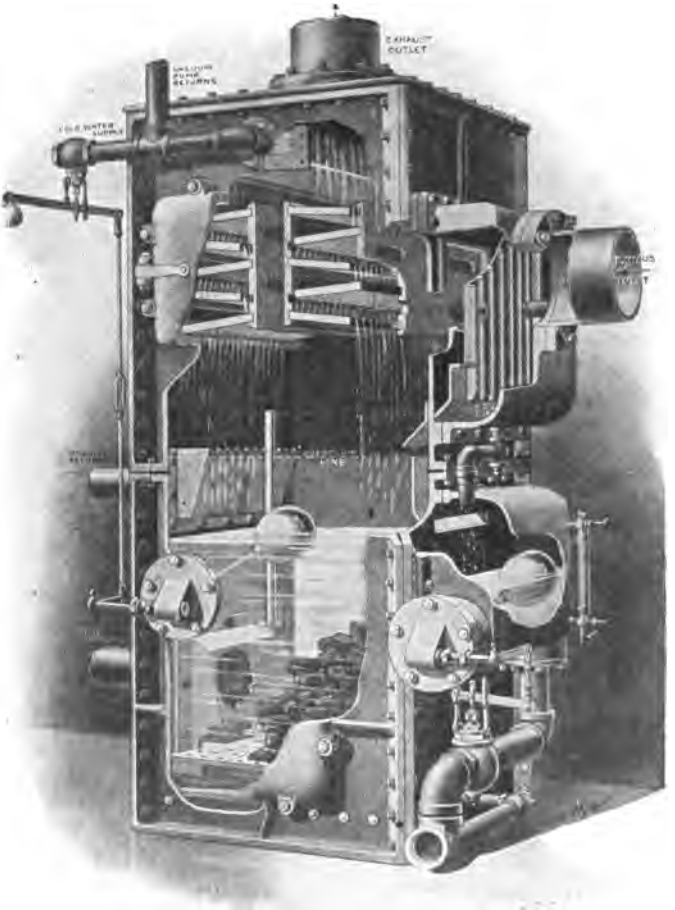


Fig. 37. Heater with Coke Fitter.

the steam is allowed to pass through the heater, the latter when only a portion of the exhaust from the engines is allowed to enter.

A very essential appliance used with exhaust-steam heating is the *pressure-reducing valve*, which makes good with live steam any de-

ficiency in exhaust that may occur. By adjusting the weight, any desired pressure, within limits, may be obtained.

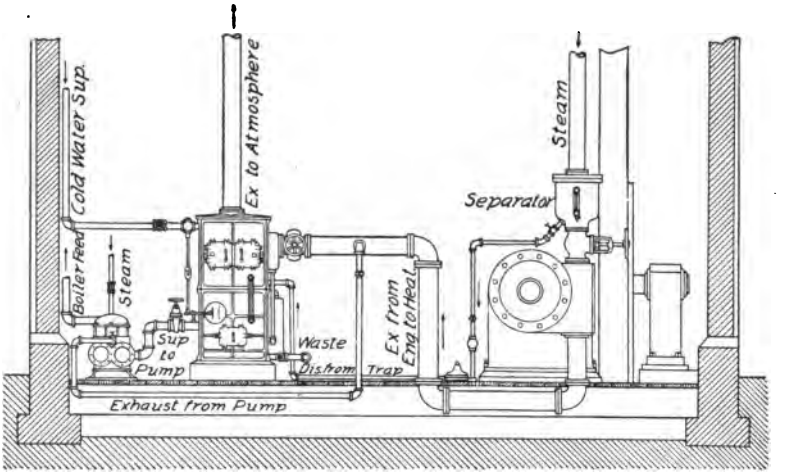


Fig. 38. Method of Making Connections when All the Steam is Allowed to Pass Through the Heater.

A *back-pressure valve* must be used with exhaust-steam heating, to regulate the pressure to be carried. It also acts as a safety-valve in case of over-pressure from any cause.

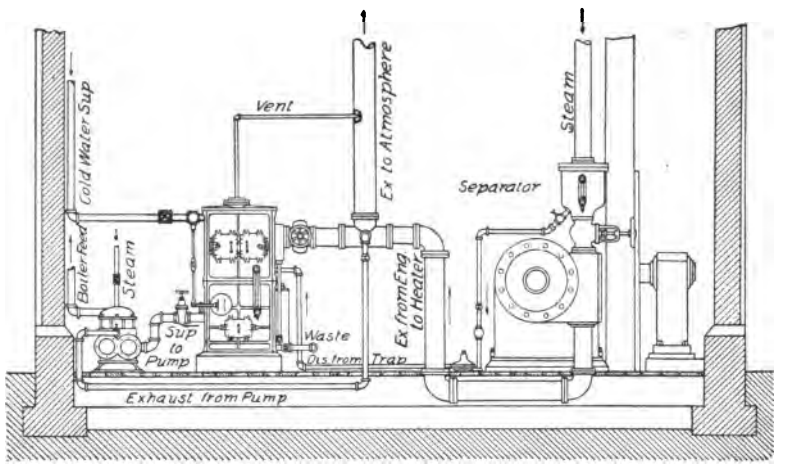


Fig. 39. Method of Making Connections when Only a Portion of Exhaust from Engine is Allowed to Enter.

Heating systems are sometimes arranged by bringing to them live steam to be reduced in the building to any desired pressure by a reduc-

ing valve. In such cases there is no back-pressure valve, therefore a safety-valve should be placed on the main to act in case of trouble with the reducing valve and prevent too great a pressure on the radiators.

A by-pass should be used in connection with all pressure-reducing valves, to provide for overhauling them. A steam gauge connected not less than 6 feet from the valve on the low pressure side is a necessary attachment.

With exhaust-steam heating, an exhaust head should be placed at the top of the vertical exhaust main, to condense, as far as possible, the steam passing through it.

The drip pipe from the exhaust should be connected with the drip tank; or, if the exhaust has been passed through a first-class separator, it may, if desired, be returned to the feed-water heater.

When a closed type feed-water heater is used (see Fig. 40), a separate tank must be provided for the returns from the heating systems. High-pressure drips are trapped to this tank. In the case of the heater shown in Fig. 37, the live-steam returns are trapped to it. A common type of trap is shown in section in Fig. 41. In the position shown, the float or bucket hinged as shown, is held up by the buoyancy of the water, and keeps the valve at the upper end of the spindle in contact with the seat, preventing the escape of steam entering with the water through the inlet. The water, rising around the bucket, overflows it and overcomes its buoyancy, causing it to fall and open the valve, the steam pressure on the water then forcing it out of the bucket until a point is reached where

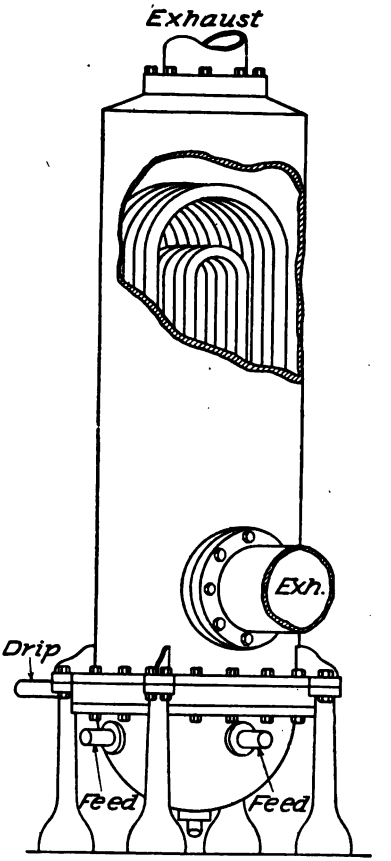


Fig. 40. Closed Type Feed Water Heater.

the buoyancy of the bucket again comes into play and closes the valve until the action is again repeated.

An extremely simple form of float trap is shown in Fig. 42, the hollow float raising the spindle and valve, permitting water to escape,

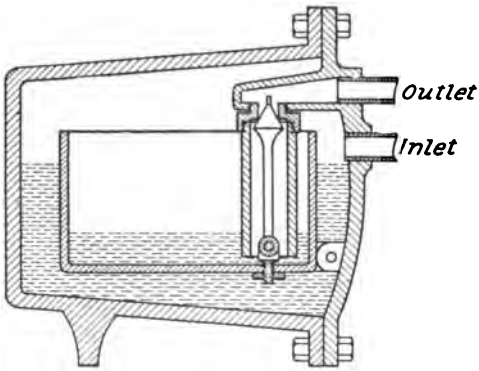


Fig. 41. Common Type of Trap

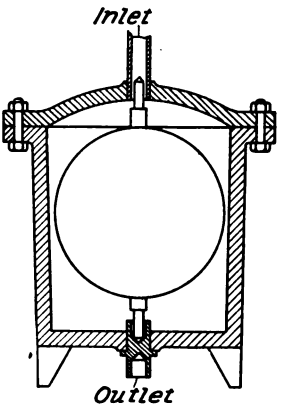


Fig. 42. Float Trap

but falling and thus closing the outlet when the level reaches a point too low to cause the ball to float, thus preventing the escape of steam.

Special forms, known as *return traps*, are used in small plants for returning to the boiler the condensation from the heating system.

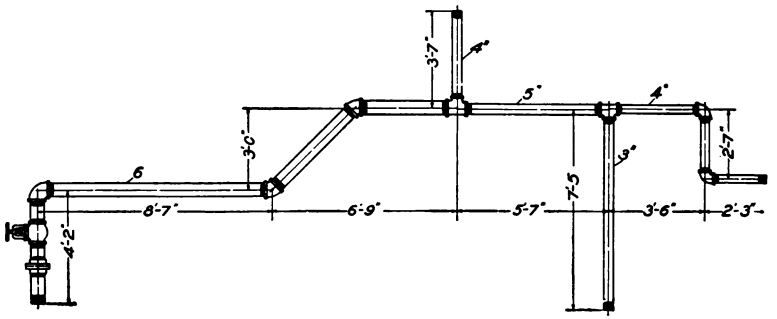


Fig. 43. Dimensioned Sketches for Cutting Pipe

In large installations of 15,000 square feet and above, it is advantageous to run boilers at high pressure and reduce for heating, on account of maintaining a uniform pressure on the heating system. In this case, two pressure reducing valves should be installed, one to take care of maximum heating requirements, and the other for

average requirements. This reduces the wear on the large valve very materially.

MODIFIED SYSTEMS OF STEAM HEATING

It is beyond the scope of this course to go into the details of the various modified or patented systems of steam circulation, yet it seems advisable to point out the essential features of certain of these systems. The Webster and Paul Systems will be found described in Part III of the Instruction Paper on Heating and Ventilation.

Thermograde System. With this two-pipe system air valves are omitted; the supply valve on each radiator is of a special construction designed to be set to admit quantities of steam under different conditions—to fill the radiator $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, or entirely full of steam. On the return end of each radiator is placed a so-called *auto-valve*, designed to permit the escape of air and water into a return pipe open to the atmosphere at the top. In the case of large buildings the water flows by gravity to a tank, from which it is pumped to the boilers.

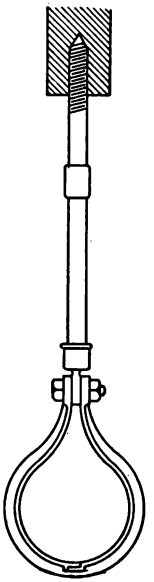


Fig. 44. Hanger

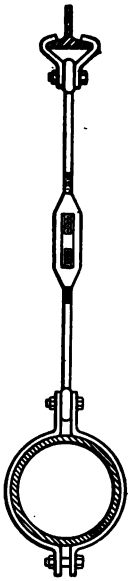


Fig. 45. Adjustable Hanger for Large Pipe

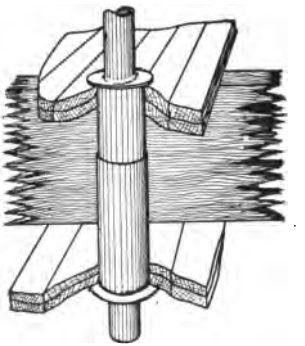


Fig. 46. Sleeve for Encasing Pipe

Some of the advantages claimed for this system are:—Absence of air-valves and air-lines; control of the heat emitted, by means of the special controlling valve at the supply end of each radiator. The piping is the same as for ordinary gravity systems.

Vapor System. This system is designed, as its name implies,

to work on a very low pressure. The radiators, preferably of the hot-water type, must have considerably more surface than with low-pressure steam heating. A special valve is placed at the supply end of each radiator, designed to admit any desired volume of steam.

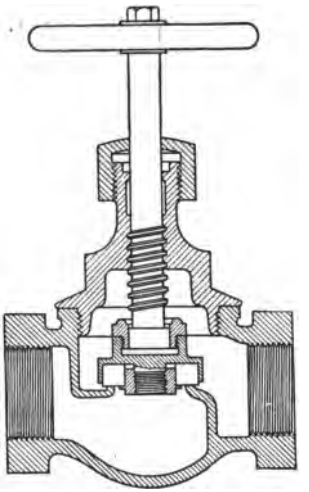


Fig. 47. Globe Valve.

A little trap or water-seal fitting is connected with the return end of each radiator, a small hole being provided above the water line to permit the escape of air. All returns are joined in the basement and discharge to an open water column alongside the boiler, any steam in the returns being condensed by passing into a coil provided for the purpose.

No safety valve is required with this system. In case of an excess of pressure in the boiler, the water is backed out into the column above mentioned; a float is raised; and dampers are closed.

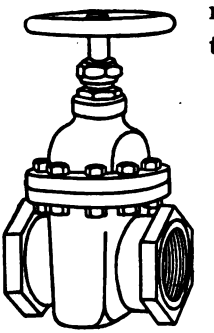


Fig. 48. Gate Valve.

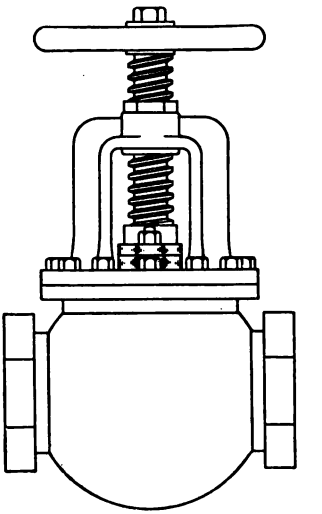


Fig. 49. Iron Body Globe Valve.

The advantages claimed are:—Complete control of the heat given off by the radiators by means of the special regulating valve on each; absolute safety; small pipes; absence of air-valves.

Mercury Seal Vacuum Systems. In one of these systems, commonly used with gravity-return apparatus, air-valves similar to those shown in Fig. 55 are placed on the radiators, and the air-lines connected with a main line discharging through a mercury seal or column, the function of which is to seal the end of the pipe and prevent the entrance of air after the air from the system has been expelled by

raising the steam pressure. In another mercury seal system, air-valves are omitted and "retarders"—so called—are placed at the return ends of radiators.

With a tight job of piping when the air in the system has once been got rid of, the plant may be run for some time—or until air leaks in again—at a pressure less than the atmosphere and with radiators at temperatures corresponding to those of hot-water radiators.

Among the claims made for this system are:—Wide range of temperature in the radiators, secured by vary-

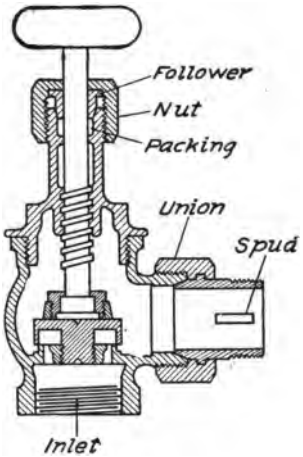


Fig. 50. Radiator Angle Valve

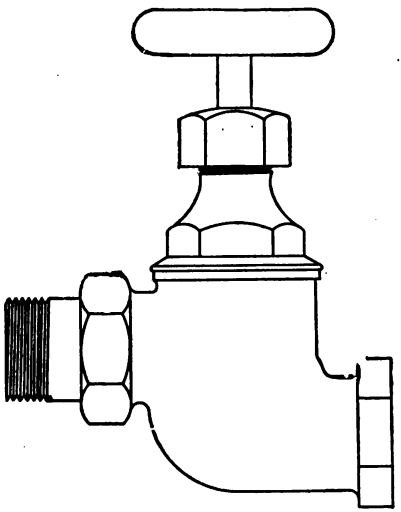


Fig. 52. Radiator Offset Valve.

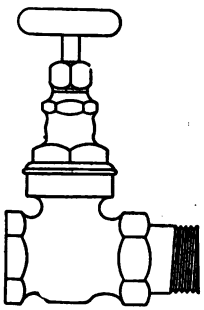


Fig. 51. Radiator Straightway Valve

ing the degree of vacuum; the advantage of a hot-water heating system without large radiators, since steam under pressure can be carried in the radiators in cold weather.

PIPE AND FITTINGS

Pipe. Pipe for heating systems should be made of wrought iron or mild steel. Sizes up to 1¼ inches diameter inclusive, are butt-welded and proved to 300 pounds' pressure; above that size they are lap-welded and tested to 500 pounds' pressure.

TABLE VIII

Standard Weight Pipe Dimensions and Data

Diameters (Inches)			Areas (Square Inches)			Miscellaneous						
Nominal Diameter	Actual External Diameter	Actual Internal Diameter	External Area	Internal Area	Area of Metal	Thickness of Metal	Linear Feet per Square Foot of External Surface	Linear Feet to Contain One Cubic Foot	Pounds of Water per Linear Foot	Nominal Weight of Pipe per Foot (Pounds)	Threads per Inch	Taper of Threads per Inch of Screw
⅛	.405	.269	.1288	.0568	.0720	.068	9.44	2,500.	.024	.241	27	¾
¼	.540	.364	.2290	.1041	.1249	.088	7.075	1,385.	.044	.42	18	¾
⅜	.675	.493	.3578	.1909	.1669	.091	5.657	751.5	.082	.559	18	¾
½	.840	.622	.5542	.3039	.2508	.109	4.502	472.4	.132	.837	14	¾
¾	1.050	.824	.8659	.5333	.3326	.113	3.637	270.	.23	1.115	14	¾
1	1.315	1.047	1.3581	.8609	.4972	.134	2.908	166 9	.373	1.668	11½	¾
1¼	1.660	1.380	2.1642	1.4957	.6685	.140	2.301	96 25	.648	2.244	11½	¾
1½	1.900	1.610	2.8353	2.0358	.7995	.145	2.01	70.65	.883	2.678	11½	¾
2	2.375	2.067	4.4301	3.3558	1.074	.154	1.611	42.36	1.454	3.609	11½	¾
2½	2.875	2.467	6.4918	4.7800	1.712	.204	1.328	30.11	2 072	5.739	8	¾
3	3.500	3.066	9.6211	7.3827	2.238	.217	1.091	19.49	3.202	7.536	8	¾
3½	4.000	3.548	12.566	9.886	2.680	.226	.955	14.56	4.285	9.001	8	¾
4	4.500	4.026	15.904	12.730	3.174	.237	.849	11.31	5.517	10.665	8	¾
4½	5.000	4.508	19.635	15.960	3.675	.246	.765	9 03	6.908	12.34	8	¾
5	5.563	5.045	24.306	19.985	4.321	.259	.629	7.20	8.668	14.502	8	¾
6	6.625	6.065	34.472	28.886	5.586	.280	.577	4.98	12.52	18.762	8	¾
7	7.625	7.023	45.664	38.743	6.921	.301	.501	3.72	16.79	23.271	8	¾
8	8.625	7.981	58.426	50.021	8.405	.322	.444	2.88	21.68	28.177	8	¾
10	10.750	10.018	90.763	78.822	11.94	.366	.355	1.80	34.17	40.065	8	¾
12	12 750	12.000	127.68	113.09	14.59	.375	.293	1.235	49.02	48.985	8	¾

Circumference = Diameter × 3.1416.
1 cu. ft. = 7½ gallons.
1 gallon = 231 cu. inches.

1 cu. ft. of water weighs 62.4 lbs.
1 gallon of water weighs 8⅓ lbs.

Pipe is shipped in lengths of 16 to 20 feet, threaded on both ends and fitted with a coupling at one end.

It is well, as a rule, to have pipes $2\frac{1}{2}$ inches in diameter and larger cut in the shop from sketches. These should give the distances from end to center, or center to center, and should state the size and kind of valves, whether flanged or screwed fittings are to be used, and in a general way should follow Fig. 43.

The dimensions of standard pipe are given in Table VIII.

NOTES ON WROUGHT-IRON PIPE

(Furnished by the Crane Company, Chicago, Ill.)

WROUGHT-IRON PIPE:—This term is now used indiscriminately to designate all butt- or lap-welded pipe, whether made of iron or steel.

MERCHANT PIPE:—This term is used to indicate the regular wrought pipe of the market, and such orders are usually filled by the shipment of soft steel pipe. The weight of merchant pipe will usually be found to be about five per cent less than card weight, in sizes $\frac{1}{8}$-inch to 6-inch, inclusive; and about ten per cent less than card weight, in sizes 7-inch to 12-inch, inclusive.

FULL-WEIGHT PIPE:—This term is used where pipe is required of about card weight. All such pipe is made from plates which are expected to produce pipe of card weight; and most of such pipe will run full card to a little above card, but, owing to exigencies of manufacture, some lengths may be below card, but never more than five per cent.

LARGE O. D. PIPE:—A term used to designate all pipe larger than 12-inch. Pipe 12-inch and smaller is known by the nominal internal diameter, but all larger sizes by their external (outside) diameter, so that "14-inch pipe," if $\frac{3}{8}$ inch thick, is $13\frac{1}{4}$-inch inside, and "20-inch pipe" of same thickness is $19\frac{1}{4}$-inch inside.

The terms "Merchant," or "Standard pipe," are not applicable to "Large O. D. pipe," as these are made in various weights, and should properly be ordered by the thickness of the metal.

When ordering large pipe threaded, it must be remembered that $\frac{1}{4}$-inch metal is too light to thread, $\frac{5}{16}$-inch being minimum thickness.

Orders for large outside diameter pipe, wherein the thickness of metal is not specified, are filled as follows:

Fourteen, fifteen, and sixteen inch, O. D., $\frac{5}{16}$-inch or $\frac{3}{8}$-inch metal.

Larger sizes, $\frac{3}{8}$-inch metal.

This pipe is shipped with plain ends, unless definitely ordered "threaded."

EXTRA STRONG PIPE:—This term designates a heavy pipe, from $\frac{1}{4}$-inch to 8-inch only, made of either puddled wrought iron or soft steel. Unless directed to the contrary, steel pipe is usually shipped. If wrought-iron pipe is required, use the term, "Strictly Wrought-Iron Extra Strong Pipe." Extra strong pipe is always shipped with plain ends and without couplings, unless instructions are received to thread and couple, for which there is an extra charge.

This term, when applied to pipe larger than 8-inch, is somewhat indefi-

nite, as 9-, 10-, and 12-inch is made both $\frac{7}{16}$ and $\frac{1}{2}$ inch thick. Pipes $\frac{1}{2}$ inch thick are carried in stock, and furnished on open order.

DOUBLE EXTRA STRONG PIPE:—This pipe is approximately twice as heavy as extra strong, and is made from $\frac{1}{2}$ to 8 inches, in both iron and steel. It is difficult, however, to find any quantity in "Strictly Wrought-Iron," and the stock carried is usually soft steel. This pipe is shipped with plain ends, without couplings, unless ordered to thread and couple, for which there is an extra charge.

Fittings. For low-pressure heating systems, standard weight cast-iron screwed fittings are used on pipes up to 7 inches or 8 inches diameter. On larger pipes it is customary to use standard flanged fittings. Flange unions should be placed at intervals in the pipes when screwed fittings are used, to provide for readily disconnecting them in case of alterations or repairs.

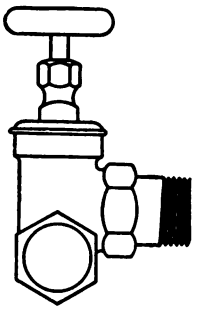


Fig. 53. Radiator Valve.

Pipe grease or various compounds are used in "making up" the joints. This material should be applied to the male threads only. When the threads of the fittings are coated with it, as is commonly done, the compound is pushed into the fitting when the pipe is screwed in, and, becoming disengaged, is likely to cause trouble later by clogging pipes, etc. For flange fittings it is the practice with many fitters to use inside gaskets, so called, cut to come just inside the bolts.

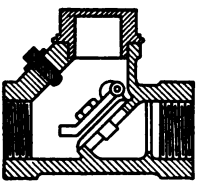


Fig. 54. Swing Check Valve.

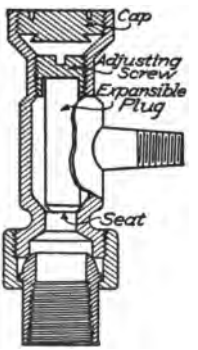


Fig. 55. Air Valve.

To describe a tee, always give the dimensions of the "run" first and the outlet last; for example, a tee 6 inches at one end, 5 inches at the other, with an outlet at the side $3\frac{1}{2}$ inches, would be known as a 6 by 5 by $3\frac{1}{2}$ tee.

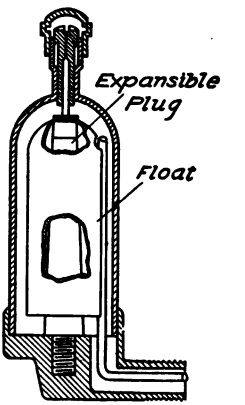


Fig. 56. Air Valve.

A tee with the outlet larger than the openings on the run, is known

as a *bullhead* tee. Tees with all three openings of the same size are known as *straight* tees.

It is far better to use reducing sockets or reducing elbows and tees, in place of straight tees with bushings.

Hangers. Pipes up to 4 inches diameter inclusive are commonly suspended by malleable-iron hangers, one type of which is shown in Fig. 44, with a gimlet point on the rod, a beam clamp being substituted when I-beams are used in place of floor timbers. One form of adjustable hanger for large pipes is shown in Fig. 45.

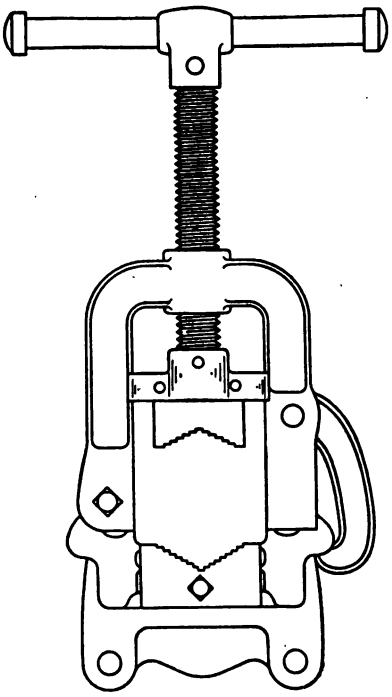


Fig. 57. Pipe Vise.

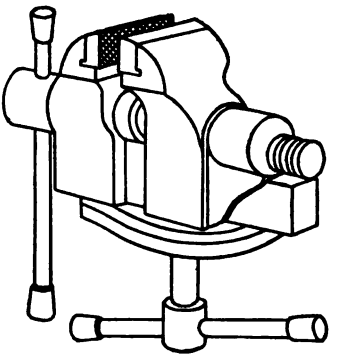


Fig. 58. Flat Jaw Vise.

Sleeves, etc. Where pipes pass through floors and partitions, they are encased in tubes with plates at floor and ceiling or at walls, as the case may be. One type of these sleeves is shown in Fig. 46.

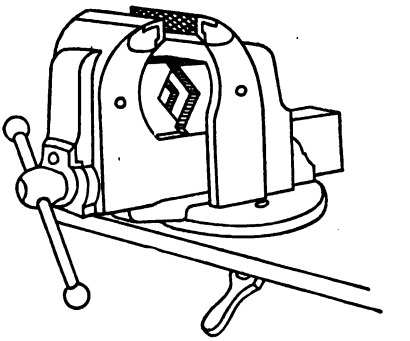


Fig. 59. Combination Vise.

Where branches from risers pass through partitions, it is often necessary to use sleeves of elliptical shape to provide for the expansion

of the risers. Sleeves for mains passing through basement walls are generally made of pieces of wrought-iron pipe of the proper length, the diameter of the sleeves to be not less than ½ inch greater than the pipe diameter if covering is omitted in walls, and 2¼ inches greater if covering is continuous along the pipe.

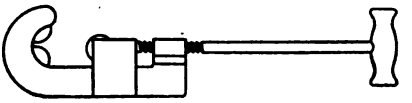


Fig. 60. Pipe Cutter.

When sleeves are placed in plastered walls, they should project a slight distance beyond the face of the plaster. When ceiling plates are made fast to risers, they should be placed at least ⅜ inch down from the ceilings, so that, when the riser expands, the ceiling plate will not be forced into the plaster.

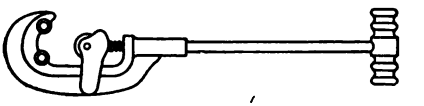


Fig. 61. Pipe Cutter.

Valves. Valves for basement piping are commonly *globe* or *gate* pattern, with rough bodies and plain iron wheels (Figs. 47 and 48). Brass or composition body valves, with screwed tops, are generally used up to 2-inch size inclusive; and iron body valves, with bolted tops, above that size (see Figs. 48 and 49). Both are made with renewable discs or seats.

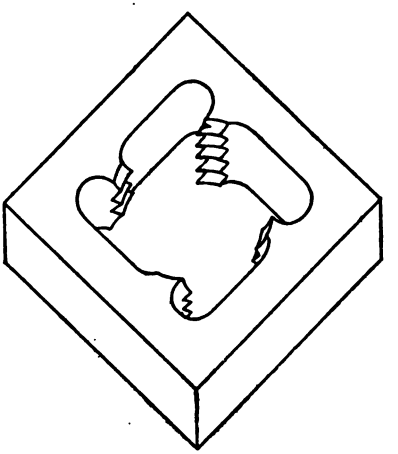


Fig. 62. Solid Die.

It is largely a matter of preference which type of valve shall be used, though of course the straightway gate valves interpose the least resistance to the flow of steam or water.

When the radiators are but little above the water line in the boiler, gate valves are frequently used on the returns to insure an easy flow of the water.

It seems hardly necessary to point out that a globe valve should be connected in the pipe with its stem horizontal, to avoid the water pocket which occurs when the stem is vertical; nevertheless fitters frequently overlook this point.

Several patterns of radiator valves are shown in Figs. 50, 51,

52, and 53. These valves are of brass or composition, rough body nickel-plated, have wood wheels, and are provided with a union. The angle valves are commonly used on first-floor radiators, those on floors

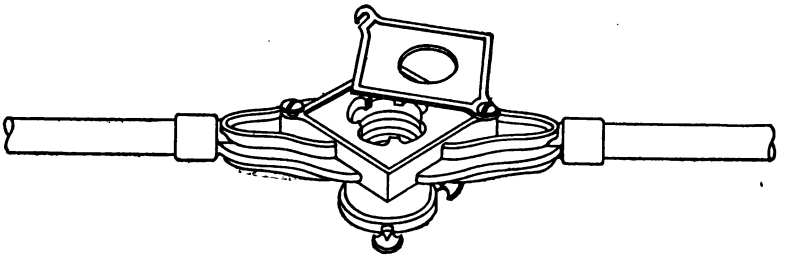


Fig. 63. Stock for Solid Dies.

above having offset or corner offset, offset globe, or straightway gate valves, according to the type of radiator and the arrangement of connections to provide for expansion.

In public buildings, the wheels are often omitted and lock-shields substituted, the valves being operated by a key.

A *swinging-check* valve is shown in Fig. 54. This type, if prop-

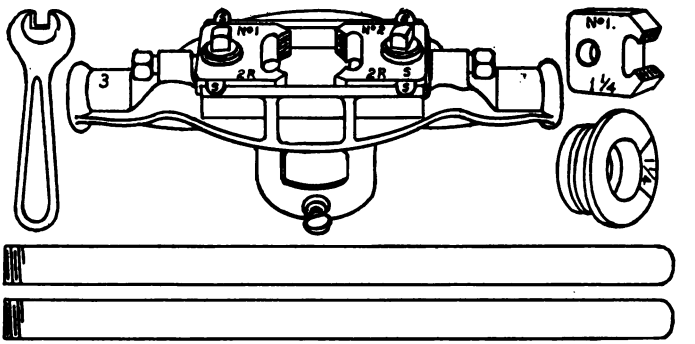


Fig. 64. Adjustable Die and Stock.

erly designed, works the easiest of any, and should be used in preference to other types when radiators are placed but little above the water line in the boiler.

Air-Valves. Numerous patterns of air-valves are on the market, some, like Fig. 55, in a general way, being fitted with a union for air-line connections leading to a convenient point of discharge in the basement. Such valves prevent the escape of steam, because of the expansion of the composition plug, which closes the opening when steam

comes in contact with it. Air and cold water, however, are permitted to escape.

The general type of air-valve shown in Fig. 56 is frequently used, many modifications of this valve having been manufactured. These

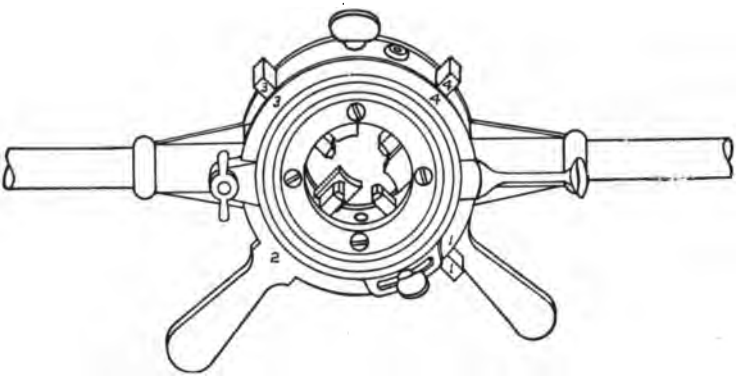


Fig. 65. Adjustable Die and Stock.

valves, as a rule, have no air-line connections, but discharge their air into the rooms; a somewhat objectionable feature. They close when steam enters them; and if water finds its way in, the float is raised and closes the outlet.

Air-valves for direct radiators have a very small opening for the

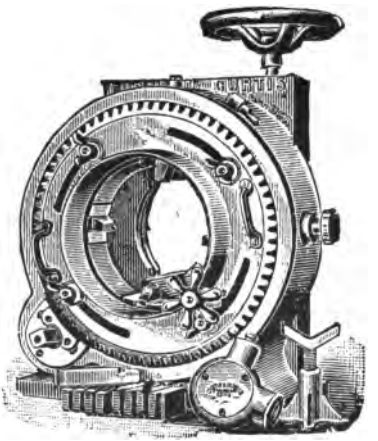


Fig. 66. Hand Power Pipe Machine.

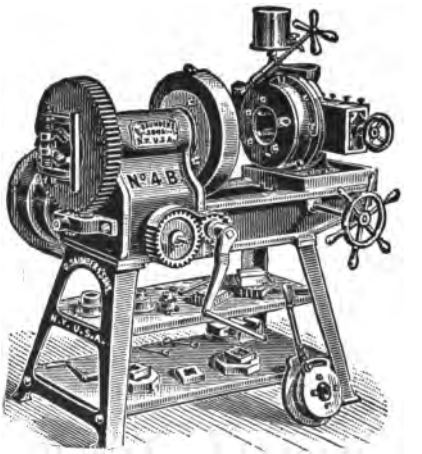


Fig. 67. Belt Power Pipe Machine.

discharge of air, scarcely larger than a pin-hole; and while these do very well for small units, they are not satisfactory for large coils or for

large groups of indirect radiators, because of the excessive time required to relieve them from air. For such heating surfaces, a type of air-valve with a much larger opening should be selected, to provide for venting the radiators or coils more quickly.

Several types of vacuum air-valves have been invented, designed to permit the escape of air from the radiators, but to prevent its reentry. If they remain tight, the steam heating system may be run in mild weather with a pressure below that of the atmosphere, and the radiator kept at a temperature below 200°.

Fig. 68 *a*. Hand Power Pipe Machine.

Pipe-Fitting Tools.—Vise and Bench. When a job is started, the first things needed are vise and bench. The latter should be firmly constructed, and rigidly held in place, the vise to be firmly secured to it by through bolts.

On a good-sized piece of work, it is well to have both a *pipe vise* and a *flat-jaw vise*, these being illustrated in Figs. 57 and 58. A heavy cover should be furnished over the screw of the flat-jaw vise, to provide a bearing for bending pipe, the end of which is passed through a ring bolted to the bench.

Fig. 59 illustrates a combination of the two vises shown in Figs. 57 and 58, making a very useful tool.

Pipe Cutters. There are several kinds of pipe cutters on the market, made with one or more cutting wheels held in a frame. All makes of cutters are operated in practically the same way, by forcing the cutting wheels into the pipe by means of a screw handle. One- and three-wheel cutters are shown in Figs. 60 and 61. The one-wheel

cutters are made in sizes for $\frac{1}{8}$-inch to 3-inch pipe; and the three-wheel cutters, for $\frac{1}{8}$-inch to 8-inch pipe.

Stocks and Dies. The several forms of dies and stocks on the market may be divided into two classes—the *solid die* and the *adjustable die.* The solid die is shown in Fig. 62, and is used for cutting both right-hand and left-hand threads. The stock in which solid dies are used is shown in Fig. 63. Adjustable dies and stocks are shown in Figs. 64 and 65. These dies may be adjusted to cut a deep or a shallow thread. It is necessary at times to cut such threads, as the fittings made by different manufacturers are not always tapped alike. To make good joints, the threads must make up tight when they are screwed into the fitting.

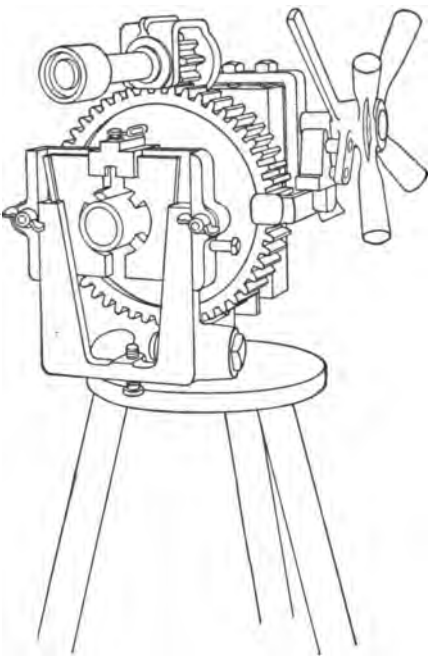


Fig. 68 *b.* Hand Power Pipe Machine.

Table IX shows the approximate distance pipes must be screwed into fittings to make a tight joint.

TABLE IX

Proper Distance to Screw Pipes into Fittings

$\frac{1}{4}$, $\frac{3}{8}$, and $\frac{1}{2}$			inch	pipe	should	be	screwed	into	fittings	approximately	$\frac{3}{8}$	in.
		$\frac{3}{4}$	"	"	"	"	"	"	"	"	$\frac{1}{2}$	"
		1	"	"	"	"	"	"	"	"	$\frac{11}{16}$	"
$1\frac{1}{4}$	and	$1\frac{1}{2}$	"	"	"	"	"	"	"	"	$\frac{5}{8}$	"
		2	"	"	"	"	"	"	"	"	$\frac{3}{4}$	"
$2\frac{1}{2}$	and	3	"	"	"	"	"	"	"	"	$\frac{7}{8}$	"
$3\frac{1}{2}$	and	4	"	"	"	"	"	"	"	"	1	"
5	and	6	"	"	"	"	"	"	"	"	$1\frac{1}{8}$	"
		7	"	"	"	"	"	"	"	"	$1\frac{1}{4}$	"
8	and	9	"	"	"	"	"	"	"	"	$1\frac{3}{8}$	"
10	and	12	"	"	"	"	"	"	"	"	$1\frac{1}{2}$	"

In all forms of stocks, whether for solid or adjustable dies, a bushing or guide must be used in the stocks to guide the dies straight onto the pipe. It is necessary that the guides for the different sizes of pipe should fit each size of pipe as closely as will allow the guide to revolve on the pipe freely. The guides should fit the stock as tightly as possible, or a crooked thread will very likely be cut.

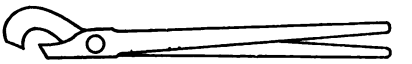


Fig. 69. Pipe Tongs.

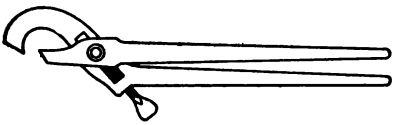


Fig. 70. Adjustable Pipe Tongs.

Plenty of good lard oil or cotton-seed oil should be used when cutting pipe. The dies must be sharp, to make good joints; and when they are changed in the stocks from one size to another, all chips of iron and dirt should be cleaned off the dies and out of the stocks, as a small chip under dies, especially under one of a set of adjustable dies, will either cut a crooked thread or strip it.

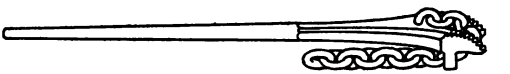


Fig. 71. Chain Tongs.

Stocks are made in sizes from $\frac{1}{8}$ inch to 4 inches. The small-size stocks and dies commonly carried in pipe-fitters' kits are made to thread pipe from $\frac{1}{8}$ inch to 1 inch inclusive, right-and left-hand; and a larger size to thread pipe from 1 inch to 2 inches inclusive, right- and left-hand. A larger-size stock is used to cut pipes over 2 inches in diameter.

There are a number of hand-power pipe machines on the market,

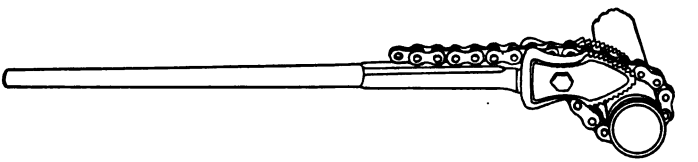


Fig. 72. Chain Tongs.

which are very convenient especially for cutting and threading pipe $2\frac{1}{2}$ inches and over. Several makes are shown in Figs. 66, and 68 *a* and 68 *b*.

Pipe Tongs. Plain tongs, like all other tools, must be kept sharp and in good order, to do good work. Many fitters object to tongs because they have to be sharpened very often, and also because they

have to carry at least one pair of tongs for each size of pipe; they prefer an adjustable wrench which will fit several different sizes of pipe.

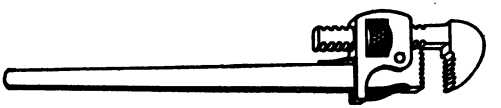


Fig. 73. Pipe Wrench.

There is one advantage in the tongs; that is, they can be worked in places where it would be impossible to use a wrench, such as making up pipe in coils, close corners, etc. Tongs should be made in such a way that when they are on the pipe, the handles will come close enough together to allow them to be gripped in one hand (see Fig. 69).

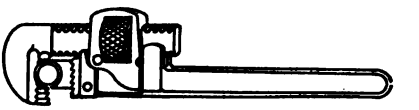


Fig. 74. Pipe Wrench.

Adjustable tongs (Fig. 70) are made to fit several sizes of pipe, the most common sizes used being for ⅜-inch to 1-inch to 2-inch, and for 2½-inch to 4-inch.

Fig. 75. Wrench for Brass or Nickle-Plated Pipe.

Chain tongs are made in all sizes and in several forms for from 1-inch up to 16-inch pipe. Some makers furnish tongs with the handle and jaws in one piece. Others have the jaws removable. Still others have the jaws so arranged that they can be removed and reversed. See Figs. 71 and 72.

Fig. 76. Wrench for Brass or Nickle-Plated Pipe.

Pipe Wrenches. Several types of adjustable wrenches are shown in Figs. 73 and 74. These wrenches will do good work if used as wrenches on the size pipe they are intended for. Some men who have little regard for tools use on a 2-inch pipe, for example, a wrench which is made to take, say, not over 1-inch pipe, the jaw of the wrench being extended as far as possible, and probably being held by only a few threads of the adjusting screw, a piece of pipe 2 or 3 feet long often being used on the handle of the wrench to

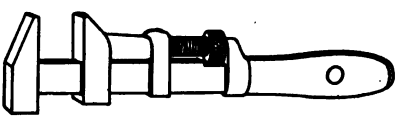


Fig. 77. Monkey Wrench.

increase the leverage. After such usage, the wrench is of little value. At times men will use wrenches in such a way as to make the strain come on the side, with the result that the wrench is badly strained if not broken.

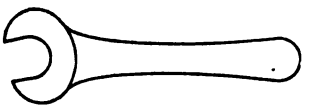


Fig. 78. Open-End Wrench.

The above described wrenches are used on wrought-iron pipe. For brass or nickel-plated pipe, wrenches like those shown in Figs. 75 and 76 should be used; otherwise the pipe will be marred and rendered unfit for use in connection with first-class work.

One of the handiest all-round tools is the *monkey wrench*, shown in Fig. 77. *Open-end* wrenches, illustrated in Figs. 78 and 79, are very handy tools, especially for use on flange fittings. Wrenches for lock-nuts are made about the same as above, only they are larger.

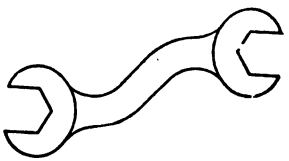


Fig. 79. Open-End Wrench.

The *return-bend wrench* is a very handy tool, and can be made by any good blacksmith. It is used principally on coil work, and is made of heavy bar iron, as shown in Figs. 80 and 81, in which two forms of this type of this wrench are shown.

Another handy tool is what is sometimes called, for want of a better name, a *spud wrench*. This is simply a piece of flat iron about

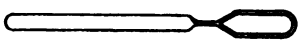


Fig. 80. Return-Bend Wrench.

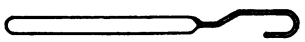


Fig. 81 Return-Bend Wrench.

10 inches long and made to fit the spuds of the unions of different sizes of union radiator valves and elbows (see Fig. 82).

Pliers. For small work, pliers may be used to advantage. Common and adjustable types are shown in Figs. 83 and 84.

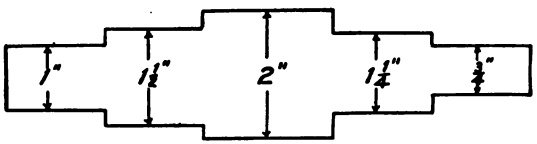


Fig. 82. Spud Wrench.

Drills, Reamers, and Taps. Pipe drills, illustrated in Fig. 85, are made slightly smaller for a given size than the taps illustrated in Fig. 86. A reamer like the one shown in Fig. 87 should be used to

start the tap, which should never be hammered in order to start the threads.

Fig. 88 shows a combined drill, reamer, and tap. Fig. 89 shows a pipe reamer for taking the burr from the ends of pipes.

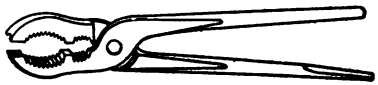


Fig. 83. Common Pliers.

Fig. 84. Adjustable Pliers.

A *ratchet drill* is illustrated in Fig. 90 and a *breast drill* in Fig. 91. Fig. 92 shows a handy tool for drilling pipe flanges which from any cause cannot be drilled in the shop.

Fig. 85. Pipe Drill.

Figs. 93, 94, 95, and 96 show *cold, cape, diamond point,* and *round-nose* chisels respectively.

A good pattern *pean hammer* is shown in Fig. 97 *a*; and a *brick hammer* is represented by Fig. 97 *b*.

Miscellaneous. Every fitter's kit should contain inside and outside *calipers*; a good set of *bits* ¼-inch to 1-inch; *bit stock*; *augers* 1¼-inch to 2-inch; *saws*; *files*; *plumb-bob*; *gimlet*; *lamp*; *oil can*; *steel square*; *tape measure*; etc.

HOT-WATER HEATING

Heaters. Hot-water heaters—or "boilers," as they are sometimes miscalled—are so nearly like the cast-iron steam boilers previously illustrated, that it is unnecessary further to describe them here.

Some makers use the same patterns for both steam boilers and hot-water heaters, while others use a higher boiler for steam, giving more space above the water line.

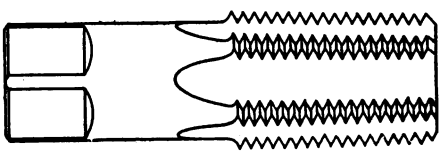


Fig. 86. Pipe Tap.

Practically the same rules should be followed in selecting a hot-water heater as those laid down for steam boilers. Although a hot-water heater is a trifle more efficient than a steam boiler—that is, more of the heat in the coal is transferred to the water, owing to the temperature of the latter being 40 degrees or more lower than in a steam boiler—nevertheless, practically the

same size of hot-water heater or steam boiler is required to heat a given space.

It is well to equip the heater with a regulator, of which a number of good ones are manufactured, in order to control the drafts by variations in the temperature of the water, the regulator being set to maintain any desired temperature in the flow pipe.

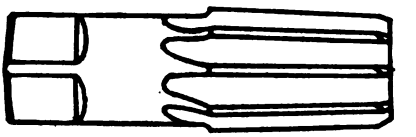


Fig. 87. Reamer.

Capacity of Heaters. Hot-water heater capacities are based, as a rule, on an average water temperature of 160° in the radiators, when placed in rooms to be kept at 70° F.

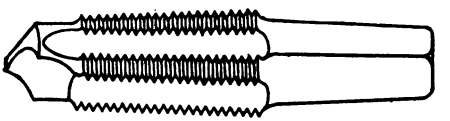


Fig. 88. Combined Drill, Reamer and Tap.

If the *closed-tank system* is used, the radiator temperatures may be 220° to 230° or more; hence, if any attention is to be given to the manufacturers' heater rating, the radiation must be reduced to the equivalent radiation in heat-emitting capacity of radiators at 160°.

This is very easily computed, since the heat given off by a radiator is proportional to the difference in temperature between the water in the radiator and the air surrounding it. This, in the first case, is 160° less 70°,

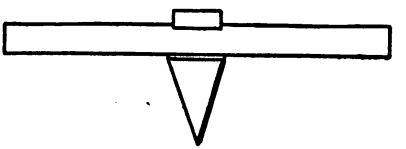


Fig. 89. Pipe Reamer for Taking the Burr from Ends of Pipe.

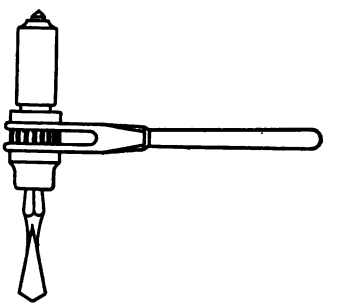


Fig. 90. Ratchet Drill.

or 90°; and in the other case, say, 225° less 70°, or 155°; that is, one foot of radiating surface at 225° will give off $\frac{155}{90}$ of the heat given off at 160°; therefore, a job with 900 square feet, for example, at 225° would be equivalent in heating power to $\frac{155}{90} \times 900 = 1550$ square feet at 160°, and a boiler with the higher rating would be required

It is always well to check the boiler rating as explained under "Steam Heating," except that in hot-water heating only 150 heat units are allowed per hour per square foot of radiating surface.

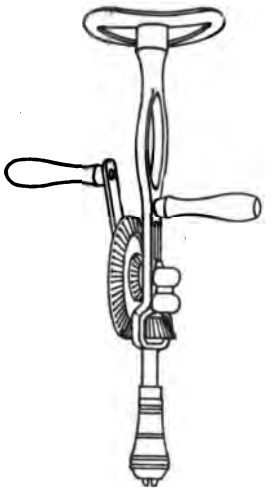


Fig 91. Breast Drill.

Of the heat given off by the coal, it is safe to assume that 8000 heat units per pound are transferred to the water in the heater.

Suppose there are 900 square feet of radiation on the job. Add $\frac{1}{3}$ to cover the loss of heat from pipes; total = 1200 square feet. Assume that in coldest weather 5 pounds of coal are burned per hour on each square foot of grate; that is, $5 \times 8000 = 40{,}000$ heat units are transferred to the water in the heater. The heat given off per hour by the radiators and pipes is $1200 \times 150 = 180{,}000$ heat units. This, divided by 40,000, the heat utilized per square foot of grate, equals $4\frac{1}{2}$ square feet of grate required.

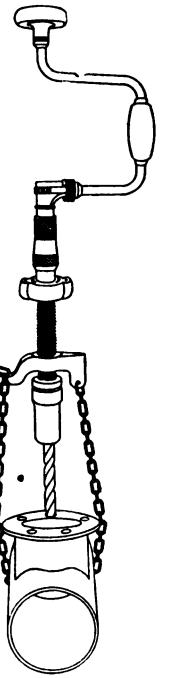


Fig. 92. Tool for Drilling Pipe Flanges.

Some judgment is necessary in assuming the rate of combustion; but this varies from about 3 pounds per square foot of grate per hour in small heaters, to 7 or 8 in larger ones, operated by a regular attendant.

HOT-WATER RADIATORS AND VALVES

Hot-water radiators have top and bottom nipple connections, as shown in Fig. 31, Part II (Heating and Ventilation). A hot-water

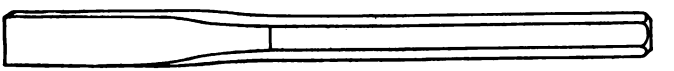


Fig. 93. Cold Chisel.

radiator may be used for steam, but a steam radiator cannot be used for hot water. The valve may be placed at the top or the bottom—it

matters little which; it is, however, more convenient, though more unsightly, at the top. The circulation will be practically as good when the valve is located at the bottom. One valve is all that is necessary,

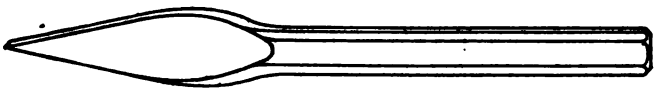


Fig. 94. Cape Chisel.

and this may best be of the quick-opening pattern, a partial turn being all that is necessary to open or close it (see Figs. 44 and 45, Part II, Heating and Ventilation).

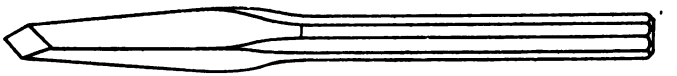


Fig. 95. Diamond-Point Chisel.

A union elbow is generally connected with the return end of a radiator (see Fig. 46, Part II, Heating and Ventilation).

Key-pattern air-valves are more frequently adopted in hot-water

Fig. 96. Round-Nose Chisel.

heating than are any types of automatic valves. They do not have to be operated often; hence the popularity of the simple and reliable air-cocks like those shown by Fig. 98.

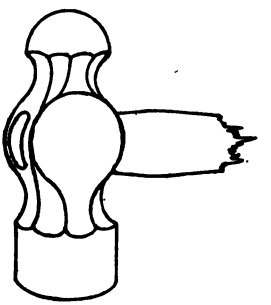


Fig. 97 *a*. Pean Hammer.

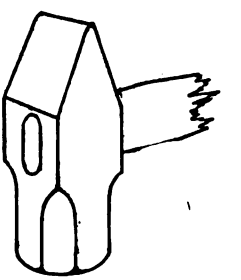


Fig. 97 *b*. Brick Hammer.

Direct-indirect hot-water radiators are seldom used, owing to the danger from freezing in case they are thoughtlessly shut off.

Indirect radiators should be of a deep pattern—say, 10 to 12 inches, or even more for use with outdoor air in a severe climate. These radiators give off far less heat per square foot than is emitted by steam radiators; hence they should be deeper, to bring the air up to proper temperature.

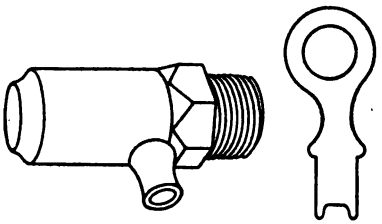


Fig. 98. Air Cock.

HOT-WATER PIPING

Heater Connections. Where only one heater is used, the connections are practically the same as for steam heating, except that no check-valves are used.

Where two boilers are to be connected and arranged to be run independently or together, valves must be inserted somewhat as shown

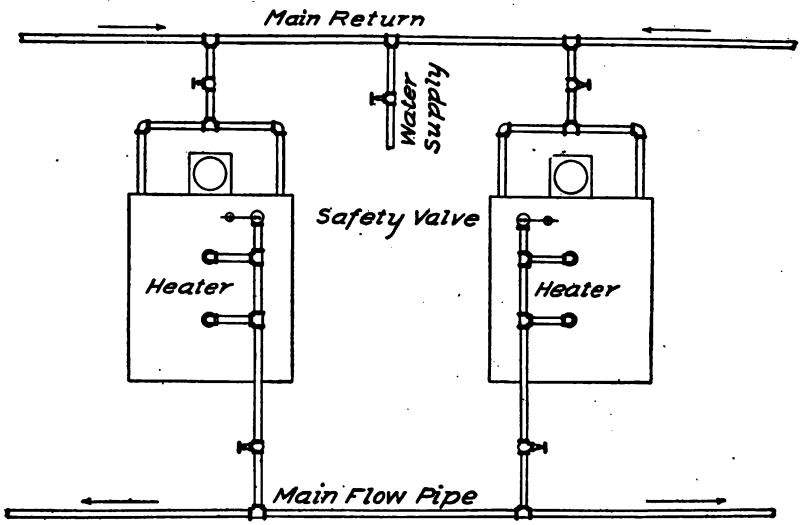


Fig. 99. Arrangement of Valves for Two Boilers which are to Run Independently or Together.

by the plan view represented in Fig. 99. It is important that safety-valves be used with this arrangement, as, in case one boiler is shut down and then fired up without opening the stop-valves, the pressure due to the expanding water will burst the heater.

Single-Main System. The single-main system, arranged some-

what like the circuit system in steam heating, is sometimes employed for hot-water heating. Fig. 100 shows the arrangement of this system. The supply branches are taken from the top of the main, where the water is hottest; and the returns are connected at the side, the cooler water passing along the lower portion of the pipe back to the heater. On systems of considerable size, this arrangement of piping causes the water in the supply main to cool more rapidly as the distance from the heater increases than in systems where the supply and return water are kept separate.

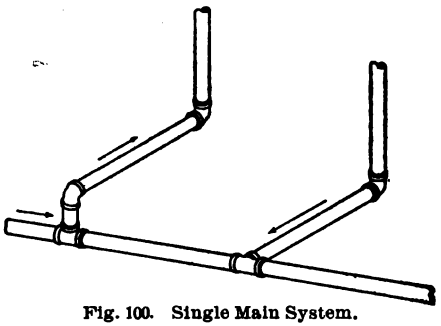


Fig. 100. Single Main System.

Two-Pipe Up-Feed System. With the two-pipe up-feed system, the pipes should be pitched up from the boiler 1 inch in 10 feet, if possible. Pockets in which air can collect must be avoided, as air will cut off the flow as much as a solid substance in the pipe would do.

In the basement, the branches near the boiler should be taken from the side of the flow main, in order to favor the branches farther

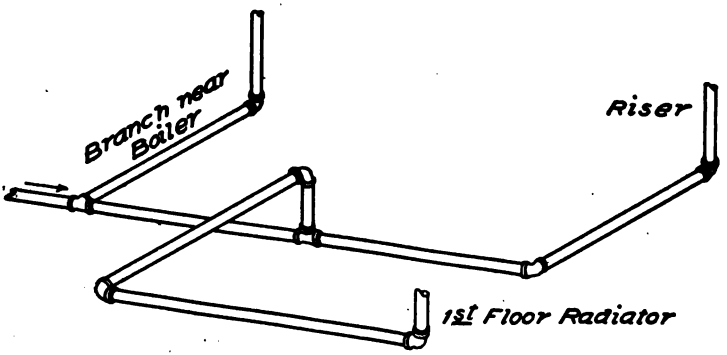


Fig. 101. Two-Pipe Up-Feed System.

away, which should be taken from the top of the main. First-floor radiators should be given the preference, as to ease of flow in their connections, over riser connections with the floors above. If possible, feed the last first-floor radiator on a line before branching to riser. Fig. 101 illustrates the above points.

Keep the mains near the ends of long runs ample in size, even if somewhat larger than stated in the table, if runs are long and crooked. No chances should be taken in regard to insuring the proper circulation of water in the system. Use no horizontal pipe smaller than 1¼-inch.

Return mains pitch in the same direction as the flow pipes, and

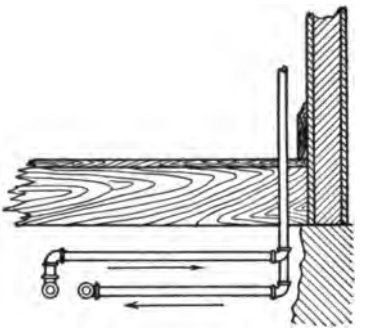


Fig. 102. Connections for Return Mains.

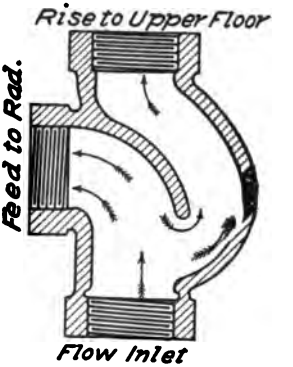


Fig. 103. Distributing Fitting.

are generally paired with them, the connections being made on the side as shown in Fig. 102, or at an angle of 45 degrees.

The risers should be arranged to favor the radiators on the lower floors, since the water tends to rise and pass by the lower radiators. Distributing fittings, as shown in Fig. 103, are often used for this purpose, or the pipes may be arranged as shown in Fig. 104. Some labor is saved by the use of the special fittings described.

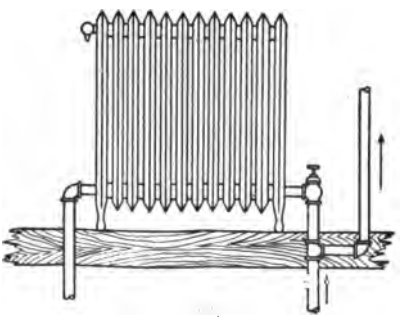


Fig. 104. Arrangement of Pipes.

Overhead-Feed System. Where attic space is available, the overhead-feed system presents certain advantages over the two-pipe up-feed method of piping. In residences, single risers are used, these serving for both supply and return, the water entering the top of the radiator and flowing back into the same riser from the lower opening in the radiator. No air-valves are necessary, all air passing up the risers and out through the vent, on the expansion tank. The overhead mains are connected with a rising main large enough to

supply all the surface; these mains may be run around the building near the walls, as in the one-pipe steam circuit system; or may be carried down the middle of the building, with long branches extending to the risers near the walls, it being assumed that the radiators will be located near the exposed parts of the building.

The mains and branches should pitch down toward the risers, permitting the air to escape freely to the expansion tank (see Fig. 105).

Special care should be used in hot-water heating, to secure an easy flow. The ends of the pipes should be reamed, and long-turn

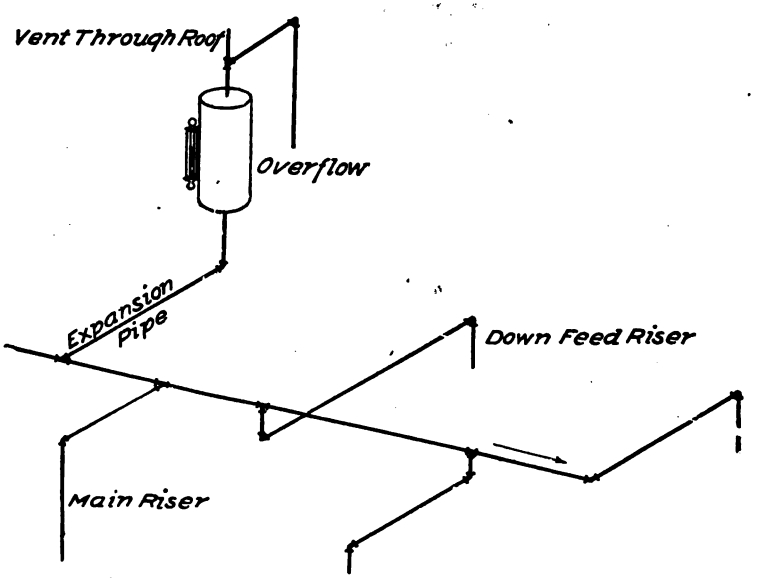


Fig. 105. Showing the Mains and Branches Pitched Down Towards the Risers.

fittings used for first-class work, although, if the piping is generously proportioned, standard fittings will answer. A hot-water thermometer should always be placed on the boiler or near it, in the flow-main.

Radiator Connections. For direct radiators, the connections are commonly 1-inch for sizes up to 40 square feet; 1¼-inch, for sizes of 72 square feet; 1½-inch to 2-inch for sizes larger than 72 square feet. On floors above the first, the connections may be made smaller if the horizontal runs are short, the sizes to conform to table.

Expansion-Tank Connections. About the simplest arrangement of expansion-tank connections is shown in Fig. 106. The expansion pipe is commonly connected with a return line in the basement, there being

less likelihood of the water boiling over in case of a hot fire with this arrangement than when the expansion pipe is merely an extension of a supply riser. There must be no valve on this pipe, as its closure would almost certainly result in a bursting of some part of the system.

Great pains must be taken to guard against the freezing of the expansion pipe. If there is any danger whatever, a circulating pipe should be added, as shown, this pipe being connected with one of the flow-pipes or supply risers, to insure a continuous circulation.

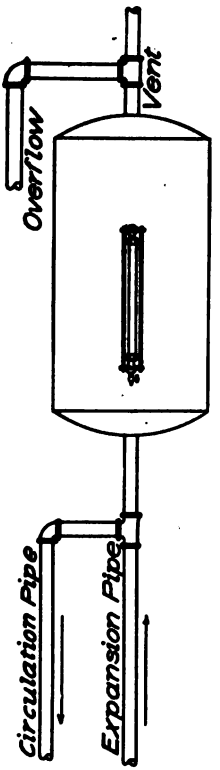


Fig. 106. Expansion Tank Connections.

Open-Tank versus Pressure System. The open-tank system, although having its disadvantages, is generally to be preferred to the pressure or closed-tank system. With the open-tank system, the water cannot get much above 212° at the heater, without boiling in the expansion tank and blowing part of the water out of the system, causing, meanwhile, objectionable noises in the system. On the other hand, the open expansion tank into which the water can freely expand when heated is the best possible safety device to prevent overpressure.

With the closed-tank system, a safety-valve is used. If it operates properly, well and good; otherwise an element of danger is introduced, and, in case an excessive pressure is developed, the heater becomes far more dangerous than a steam boiler, owing to the much greater volume of water in the system.

With this system, two safety-valves with non-corrosive seats should be used, unless some well-tested device of demonstrated merit designed especially for this purpose is adopted.

The advantage of the closed-tank system is that smaller radiators may be used, since they can be heated as hot with water under pressure as they would be if heated with steam.

When full street pressure is applied to a system, and no expansion tank is used, the radiators are subjected to an unnecessary

strain; and in case of rupture in any part of the system, much greater damage results, than would be the case with an open-tank system.

System of Forced Circulation. In extensive systems the water is kept in circulation by pumps, which are capable of producing a much higher velocity in the pipes than could be secured by gravity. This system is used principally in connection with power plants, the water being heated in tubular heaters, by means of the exhaust steam from the engines. Much smaller supply mains may be used in this system than with steam heating, because of the greater capacity of water for carrying heat. On the other hand steam returns are smaller.

Table X gives the capacities of expansion tanks:

TABLE X

Radiation Capacities of Expansion Tanks

Capacity of Tank	Direct Radiating Surface to which Tank is Adapted
5 gallons	200 sq. ft.
10 "	450 " "
15 "	700 " "
20 "	1000 " "
30 "	1400 " "
40 "	1900 " "
50 "	2400 " "
60 "	2900 " "

COMPUTING RADIATION

Computing Direct Radiation. The process of computing hot-water radiating surface is precisely the same as that explained for ascertaining the amount of steam radiation required for a given case, with this important exception: the hot-water radiators give off only about $\frac{3}{5}$ as much heat per square foot as is emitted by a steam radiator; hence calculations must be based on an allowance of 150 heat units per square foot of direct radiating surface per hour, instead of 250 heat units used in connection with steam-heating work.

It has been stated that direct-indirect hot-water radiators are rarely used. In case, however, it is desired to compute the amount of this class of radiation for a given service, proceed as explained for steam heating, but allow only $\frac{3}{5}$ as much heat emitted per square foot as that given off by steam radiators.

Computing Indirect Radiation. With indirect hot-water radia-

tion in connection with the open-tank system, the radiators must be deeper than for steam heating, in order properly to heat the air.

The greater depth retards the flow of air; and since the water is at a much lower temperature than steam, the heating capacity of indirect extended-surface hot-water radiators should be taken at not far from 300 heat units per square foot per hour, as against 400 or more heat units for indirect steam radiation.

To compute the amount of radiation required, proceed as explained for indirect steam heating; that is, compute the amount of direct radiation as pointed out under the preceding heading, then add not less than 60 per cent to this amount, to ascertain the indirect radiating surface required.

This method, though perhaps crude, has the advantages of being simple and of affording a check on the work, since one soon knows by experience about what the ratio should be to heat a room of given size by direct radiation. For example, take a room with 3000 cubic feet, to heat which the ratio for direct radiation should be, say, 1 square foot to 30 cubic feet, giving a 100-square foot radiator. Adding 60 per cent for indirect radiation, gives 160 square feet, or a ratio of 1 square foot to a little less than 20 cubic feet of space.

Indirect hot-water radiators with extended pins or ribs will, with the open-tank system, give off not far from 250 to 300 heat units per hour per square foot of extended surface.

DUCTS AND FLUES

Areas of Ducts and Flues. When indirect radiation is installed primarily for heating, ventilation being a secondary consideration, it is desirable to make the flues somewhat smaller in proportion to the heating surface than is done with steam heating. If the flues are made too large, the flow through the radiators will be too rapid, and the air will not get hot enough. It costs far more in fuel to heat with a large volume of moderately warmed air than with a smaller volume of hotter air.

Duct and flue proportions for hot-water heating should be approximately as follows:—Cold-air ducts, $\frac{3}{4}$ to 1 sq. in. per sq. ft. of indirect radiating surface; first-floor flues, $1\frac{1}{4}$ to $1\frac{1}{2}$ sq. in. per sq. ft.; second-floor flues, 1 to $1\frac{1}{4}$ sq. in. per sq. ft.; third-floor flues and above, $\frac{3}{4}$ to 1 sq. in. per sq. ft. of surface.

The backs and sides of flues in exposed walls should be covered with non-conducting material.

Flue Velocities. The flue velocities will be somewhat lower than with steam heating, because of the lower temperature of the air. Reasonable allowance would be 250, 350, 400, and 450 feet per minute for the first, second, third, and fourth floors respectively.

Heating Water. The size of heater or steam coil necessary to heat water may be very readily determined on the heat-unit basis, if one knows the volume of water to be heated, the number of degrees its temperature is to be raised, and the time during which the heating must be done.

For example, what size of heater would be required to heat 300 gallons of water in 6 hours from 60° to 160°?

In one hour 50 gals. would be heated 100° F.; and since one gal. weighs $8\frac{1}{3}$ lbs., $50 \times 8\frac{1}{3} \times 100 = 41{,}667$ heat units would be required.

Small heaters may be counted on to transmit to the water about 7000 heat units per pound of coal burned. The rate of combustion should be assumed to be from 3 to 6 pounds per square foot of grate per hour, according to the amount of attendance it is convenient to give.

With a 4-pound rate, 28,000 heat units would be furnished per square foot of grate surface per hour for heating the water. Therefore the heat units per hour necessary to raise the temperature of the water—*viz.*, 41,667—divided by 28,000, gives the number of square feet of grate surface required, which is equal to about $1\frac{1}{2}$ corresponding to a diameter of $16\frac{1}{2}$ inches.

To determine the size of steam boiler and coil required to heat a large volume of water in a tank, proceed as follows: Take, for example, a 24,000-gallon tank, the water in which is to be heated from 45° to 75° in 10 hours. Now 24,000 gals. $\times$ $8\frac{1}{3}$ pounds $\times$ 30° rise in temperature = 6,000,000 heat units, or 600,000 heat units per hour.

Assuming 8000 heat units to be utilized per pound of coal burned at, say, a $7\frac{1}{2}$-pound rate, one square foot of grate will supply 60,000 heat units per hour; hence, 10 square feet of grate surface will be required.

There will, however, be a certain loss of heat from the tank by radiation, conduction, and evaporation; therefore, not less than, say, 12 square feet should be used in order to provide a reasonable margin.

As to the size of steam coil required, a square foot of pipe surface

surrounded by circulating water may be assumed to transmit to the water not far from 100 heat units per degree difference in temperature between the steam and the water in contact with the pipe.

Assume the steam temperature to be 230°, corresponding to a trifle more than 5 pounds gauge pressure. When the water in the tank is cold, the condensation of steam in the coil will be much more rapid than when the surrounding water becomes warmer. The average temperature of the water during the 10-hour period is 60°; but the water leaving the pipe and in contact with the upper half of its surface is at a considerably higher temperature than the main body of water in the tank; therefore, with natural circulation, it is well to make ample allowance for the effect of this skin of warm water surrounding the steam coils, and to assume that they will not give off more than $\frac{2}{3}$ as much heat as that corresponding to the difference in temperature between the steam and the water in the tank, based on 100 heat units per degree difference as stated above.

In other words, allow only $66\frac{2}{3}$—or, in round numbers, 70—heat units per hour per degree difference in temperature between the steam and the water in the tank.

If the difference in temperature is $230° - 70° = 160°$, on the basis stated, one square foot of coil would give off $70 \times 160 = 11{,}200$ heat units per square foot per hour; and since 600,000 heat units must be supplied to the water, a 53-square foot coil or slightly larger would be required, equal to about 122 ft. of $1\frac{1}{4}$-inch pipe.

MODERN BATHROOM SHOWING EXCELLENT ARRANGEMENT OF FIXTURES IN SMALL SPACE

Courtesy of the J. L. Mott Iron Works, New York City

SANITARY APPLIANCES

TRAPS

Object of Traps. There are endless varieties of traps marketed, and each shape and type may have some particular advantage for the purpose it is used.

Broadly, we can define a trap as a device holding a quantity of water and having an upper portion which dips into the water and forms the seal.

The seal should be at least 1½ inches in depth for traps up to 2 inches in diameter and may be 2½ inches deep for water closets and the large traps.

The object of the trap is to cut off from the interior of the building, by means of the water seal, the foul gases which are ever present in soil and waste pipes. To accomplish this object satisfactorily, a trap must be placed immediately under every sanitary fixture and the water seal of such trap must be kept intact, otherwise the occupants of a house may be placed in a position of false security, thinking no foul gases can pass the trap, yet the seal may be broken and dense volumes of obnoxious gases enter into and pollute the entire building.

Characteristics of Good Trap. A good trap embraces the following features: It should be free from all sharp angles and corners in which foul matter may collect or, in other words, it must be perfectly self-cleansing. It must have a good depth of water seal, yet contain only a minimum quantity of water. It must be constructed of a material which will not be acted upon by sewage or foul gases in the trap and that can be joined readily to both the sanitary fixture and the waste pipe.

Methods by Which Water Seal May Be Broken. The seal of a trap may be broken by five distinct methods, namely, evaporation, momentum, capillary attraction, leakage, and siphonage.

Evaporation. The trap seal is broken by evaporation by the drying-up of the water seal in the trap, due to the passing away of the water in the form of invisible vapor. This process

of evaporation is forever taking place not only in traps but on a large scale. All surface water, which includes the ocean, lakes, rivers, etc., is being constantly evaporated to form the clouds which produce the rainfall. To avoid the seal being broken by evaporation, the fixtures should be used periodically; or the trap should be filled with oil—an expensive method if there are a large number of traps in the building; or they may be filled with a strong salt solution. This difficulty occurs only in those buildings which are unoccupied for considerable periods or in basements or cellars where drain traps are unobserved or forgotten. For the latter an anti-siphon mechanical trap may be used.

Momentum. The water seal of a trap may be broken also by momentum, especially if the trap is of round pipe construction and badly shaped. The result of the latter is that the trap may have a small depth of water seal and yet contain a large quantity of water, having what is termed an easy flow through it. The sudden discharge of a large quantity of water from a considerable height will cause the water to attain such a velocity in its passage through the trap that only a small amount will be retained in the trap, thus breaking the seal. In the case of very high buildings, the force of the wind blowing over the terminal of the vent shaft and then suddenly changing its direction, as is often the case in squally weather, sets up oscillations so that the momentum of the moving water will occasionally break the trap seal.

Capillary Attraction. Capillary attraction is the action which causes the oil to rise in a lamp wick or causes blotting paper to absorb ink. Should a piece of rag, string, or lint catch on the outlet side of the trap and have one end of this material in the seal of the trap, the water will be drawn up along this string and allowed to flow down the soil or waste pipe. In a remarkably short time the seal will be broken. A practical experiment may be tried by the reader by procuring a glass and filling it with water. Now take a piece of ordinary darning cotton and place it in the water, allowing one end to hang over and below the outside of the glass. In a short time the glass will be emptied of water.

Leakage. The trap seal may be broken also through leakage. A leaky connection on a drum trap, a sand hole in a cast-brass

trap, or a defective packing around the trap screw will speedily break the seal. The seal of traps with weirs may also be broken by leakage. The water weir may be imperfect and the seal leak into the waste pipe without betraying the defect by outward leakage.

Siphonage. Traps introduce into plumbing the element of siphonage. This may be normal and desirable, as in the case of closets which discharge their contents by siphonic action, but undesired siphonage in fixture traps and the means of preventing it are prime factors in every plumber's work.

Ordinary siphonage can best be illustrated by a few simple diagrams showing the principles involved. In Fig. 1 is shown a

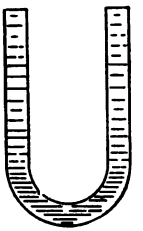


Fig. 1. U-Tube with Legs of Equal Length

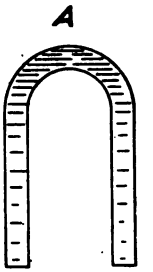


Fig. 2. U-Tube Inverted

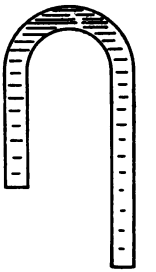


Fig. 3. Inverted U-Tube with Legs of Unequal Length

U-tube with legs of equal length filled with water. If we invert the tube, as shown in Fig. 2, the water will not run out, because the legs are of equal length and contain equal weights of water, which will pull downward from the top with the same force, tending to form a vacuum at *A*. Cohesion of the particles of water, together with equal atmospheric support of the water at the open ends of the tube, prevents any appreciable void space when the U is of short length. If one of the legs is lengthened, Fig. 3, so that the column of water is heavier on one side than on the other, the water will run out. The atmospheric pressure being practically equal on both legs, the greater weight of the water in the long end, through cohesion, pulls the water in the shorter tube up over the bend, in much the same way as an unbalanced chain would run over a pulley. The columns

of water in the tube in this case may be likened to a piece of rope hanging over a pulley; when equal lengths hang on each side, it will remain stationary; but if one end is longer and therefore heavier than the other, the whole rope will be drawn over by the longer and heavier portion.

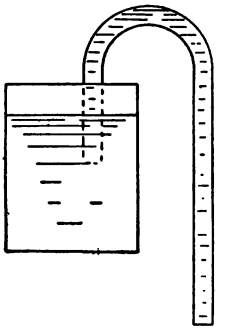


Fig. 4. A Common Siphon.

If the short leg, Fig. 3, be dipped in a vessel of water, as shown in Fig. 4, we then have the conditions necessary to form a common siphon. The atmospheric pressure, which before acted on the water at the bottom of the short leg of the tube, now becomes operative on the surface of the water in the vessel, and the flow through the tube will continue until the water-level in the vessel falls slightly below the end of the tube, admitting air and breaking the siphonic action. Gravity acts proportionally on the water of both legs of the U during siphonage, and the point of tension is therefore at the highest point of the bend.

If the bend should be pierced at the top, air-pressure would be established at both ends of each leg, and gravity would instantly empty the short leg into the vessel. It is in this manner that a crown vent to a common fixture trap breaks the flow and throws enough

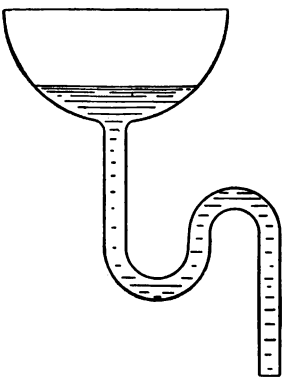


Fig. 5. Trap Fulfilling Siphonage Conditions.

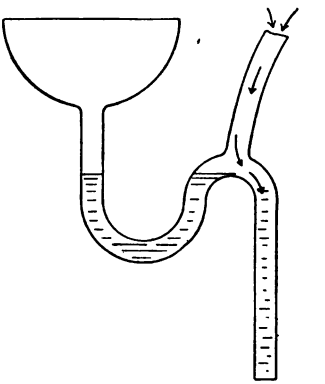


Fig. 6. Siphoning of Trap Broken by Crown Vent.

water back into the body of the trap to preserve the water-seal. Fig. 5 shows the principle of Fig. 4 applied to the trap of a plumbing fixture. If the bowl is well filled with water, so that when the stopper

is removed from the bottom, the waste pipe for some distance below the trap will be filled with a solid column of water, siphonic action like that just described will take place and the trap will be drained. A sufficient amount of water runs down from the fixture and sides of the pipe above the trap to partially provide for the seal, its full restoration being assured when a crown vent is used, by water being thrown back from the short leg of the siphon (center leg of the trap) as shown in Fig. 6.

The direct action of the water of a fixture in breaking its own trap seal by siphonage, is called *self-siphonage.* A more common form of trap siphonage in defective work, is where two or more fixtures connect with the same waste pipe, as shown in Fig. 7. In such cases, the seal of the lower fixture is more apt to be broken by the discharge of the upper. The falling column of water leaves behind it a partial vacuum in the soil pipe; and the outer air tends to rush into the pipe through the way of least resistance, which is often through the trap seal of the fixture below. The friction of the rough sides of a tall soil-pipe, even though it be open at the roof, opposed to the flow of air through it, will sometimes offer more resistance than the trap seals of the fixtures, with the result that the seals are broken, and gases from the drain are free to enter the building.

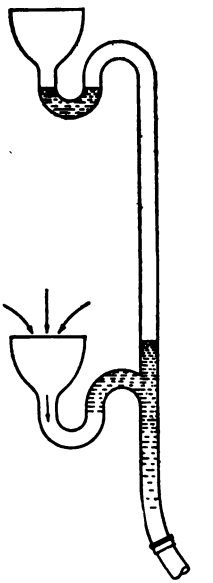


Fig. 7. Two Unvented Fixtures Connected to Same Waste Pipe, Causing Self-Siphonage.

Kinds of Traps. The kinds of fixture traps are innumerable. They can be divided into two general classes—those that seal with *water only,* and those that have a *mechanical seal* as an adjunct to that of the water. These may be again divided into *plain* and *anti-siphoning* classes.

The trap having no concealed partitions and with all its walls exposed to view, is best. If the water leaks through the wall, its defectiveness is evident, and the annoyance from the leak suggests repairing.

Of the simple *water-seal* fixture traps, the open-walled *drawn lead* is used for ordinary work. It can be had with equal-length arms or with extended inlet or outlet, so as to reach from fixture to floor or

wall without a piece of intermediate pipe. The form shown by full lines in Fig. 8 represents a full "S" pattern. When the ends are bent as per dotted lines *A* and *C*, the trap is called a *running* trap;

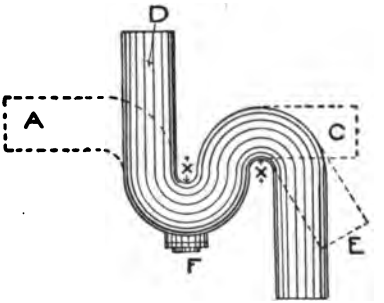


Fig. 8. "S"-Pattern Trap.

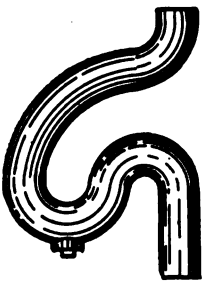


Fig. 9. A Bag Trap.

when the ends are at *D* and *C*, it is said to be a *half-S* or *P* trap; when the ends are set as at *D* and *E*, it is called a ¾-*S* trap. *F* is a clean-out screw for emptying and cleansing. The distance represented by *X* should, in a trap for ordinary purposes, be ½ to 2 inches, according to size. Frequently this distance, which constitutes the water-lock, is much reduced; and sometimes the trap is unsealed by the plumber stretching its bends in order to reach some faulty roughing-in.

In buildings where the plumbing may be left unused for weeks from time to time, as is likely in rented houses, *deep-seal* traps, or those with mechanical seals also, should be used. This point is not so important in detached houses or those rented to one family only at a time, since, when a family moves out, there is no one to suffer. But in flat buildings, where some of the flats may be vacant for a time sufficient for an ordinary seal to be broken while other families are living in the house, deep-seal traps are more essential.

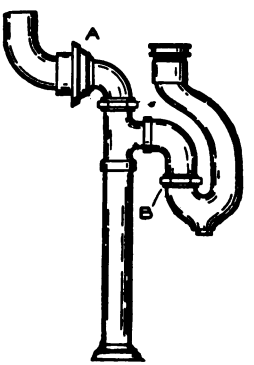


Fig. 10. Open-Wall Trap, Partly Cast.

Fig. 9 shows what is termed a *bag trap*, made to bring the inlet and outlet in the same vertical line. These traps are interchangeable with any others with straight-line outlet—for instance, as shown in Fig. 12.

An open-wall trap partly cast and partly tubing, generally made

of brass, is shown in Fig. 10, the vent connection to wall being at *A*. This form of trap generally has a swivel-joint at *B*, which is below the water line, so that the body may be swiveled to meet roughing-in openings in any direction within two diameters of the line of fixture outlet. The bag form shown is most convenient for D-shape or standing waste bowls which present the outlet comparatively near the wall. The regular "S" of this type suits bowls with center outlet, and will reach a wider range of variation in roughing-in.

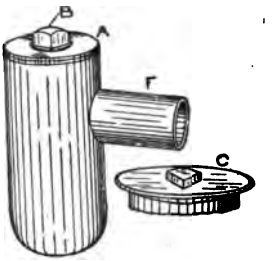


Fig. 11. Common Lead Drum or Pot Trap.

Fig. 11 shows a common lead drum or pot trap, most convenient to the plumber. It is furnished without openings, and the plumber makes bends, and wipes-in his inlet and outlet at points in the circumference most convenient to reach the fixture opening. *A* is the screw-top clean-out; and *B*, the wrench-face for turning it. The trap is furnished, when desired, with nickel-plated brass flanged cover, as shown at *C*, to screw on at the floor-level. *F* is ordinarily the outlet, the inlet being wiped-in near the bottom to give it the water-lock. This is not proper, however, as it puts the sewer air against the clean-out cover, which might leak gases into the building without betraying any evidence of its defectiveness by water leakage. To be strictly correct, *F* should be the inlet; and the outlet, in the shape of an offset, or that of an inverted P-trap without the trap-screw, should be wiped-in near the bottom in a way to retain the proper seal and thus bring the sewer air against the water-seal instead of the clean-out cover.

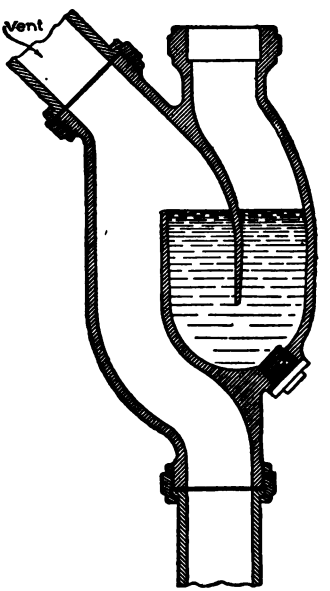


Fig. 12. Section of Flask or Atlas Trap, with Two Interior Weirs.

Traps that retain their seals by means of interior weirs are of doubtful character, even at their best; none but well-tested cast-brass

traps of such a pattern should ever be installed. Fig. 12 is a section of a *flask* or *Atlas* trap, with vent, usually made of cast brass and depending upon two interior weirs to form the seal, one retaining the water, and the other dipping into the water to prevent sewer air from getting into the house through the fixture. If the water weir of such a trap becomes defective, there is no evidence except odors by which the occupants may discover it. If the dipping weir is defective the value of the water seal is *nil*. In either case the trap is no barrier to the admission of drain air to the house.

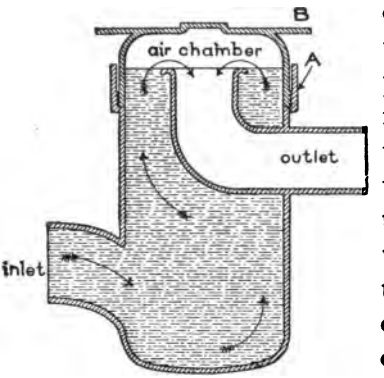


Fig. 13. Bath Trap with Submerged Inlet.

Fig. 13 illustrates a form of trap suitable for use with baths. It has a submerged inlet connection which is expanded so that the flow enters the trap at a dipping angle which produces a swirl with cleansing effect. The extension collar *A* is made so that the screw-cover *B* forms the gasket joint below the water-level. The method of providing the outlet in this trap makes it open to the same objection raised in connection with Fig. 11. This form, however, has the merit of being accessible for inspection without disturbing its service, which is impossible with the flask pattern shown in Fig. 12.

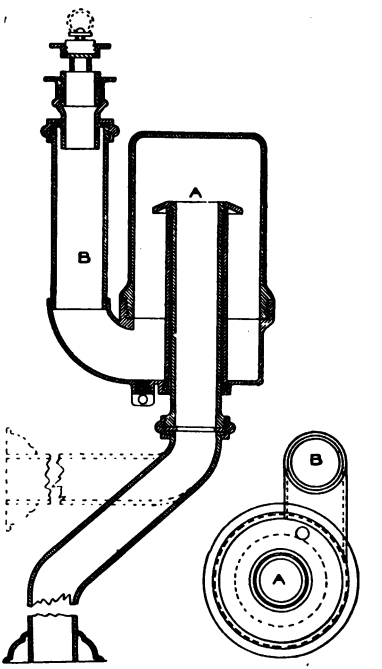


Fig. 14. Lavatory Trap with Interior Flanged Weir. Weir is Double-Walled to Betray Leakage.

The lavatory trap shown in Fig. 14, has an interior weir as shown at *A*; but the wall is doubled in such a way as to betray defectiveness by water leakage. It is made of cast metal, and is furnished

with either glass or metal dome. The strong point claimed for this trap is the cleansing effect obtained by the flange extension of the exit, as shown at *A*, deflecting some of the water, which, together with the swirling effect produced by the tangential inlet, makes the trap self-cleansing.

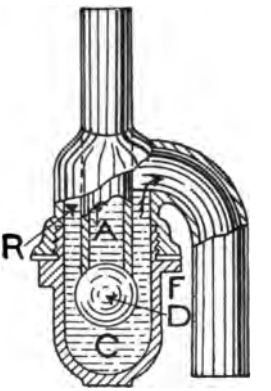


Fig. 15. Trap with Mechanical Seal Acting by Flotation.

Of the traps having a mechanical seal supplementing the water-lock, Fig. 15 is a specific type. The mechanical valve *D* is a rubber ball, lighter than an equal bulk of water, playing in the cup *C*. It acts by flotation, and presses up against the inlet *A* with a force equal to the difference in weight of the ball and the water it displaces. The body is generally made of lead; and the cup of glass, with screw-joint and gasket at *F*. This trap is proof against backwater; and, in case the waste line becomes choked below, will prevent a fixture from flooding even when others are discharged at a higher level. It has, however, several faults that counterbalance its merits. The inlet is open to the same criticisms that an interior wall of any other trap would be; the annular space at *R* accumulates filth; and the mechanical seal is worthless when most needed—that is, in the absence of the water-seal.

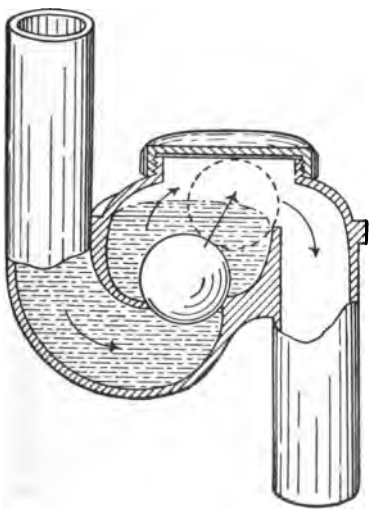


Fig. 16. Trap with Mechanical Seal Acting by Gravity.

Another mechanical seal trap, shown in Fig. 16, is the exact opposite of the previous example. The ball sinks by gravity, and effects a mechanical seal even when the water seal is absent. This trap is not so easily siphoned as a plain trap. It has a clean-out screw, and can be had with vent opening. Air from the sewer side acts against the clean-out cap through which access is had to the ball, and there are interior walls to become defective with little chance of discovery in practice.

A combined mechanical and water-seal trap, is shown in Fig. 17, in which D is a hollow, flexible ball inclosing a metal ball D^1, thus giving a resilient seating surface that finds its place by gravity in water. The arrangement is proof against back-water, and the mechanical seal is positive without the aid of water. A represents the basin; B, the basin coupling; C, the valve seat; F, a glass cylinder body; and GG, a clamp with thumb-screw G^1, for clamping the cylinder body in place. This trap holds a large amount of water, and is not likely to become unsealed from lack of use, as part of the seal is protected by the ball, and should the water evaporate, the mechanical seal is still effective. There are no interior walls through which the trap could lose its seal without betraying the fact by leakage. Generally speaking, mechanical seals in fixture traps cannot be depended upon. Anti-siphoning traps are a blessing in instances where pipe ventilation is difficult. It would be better to have none of them, however, than to attempt to supplant pipe ventilation by their use to any great extent.

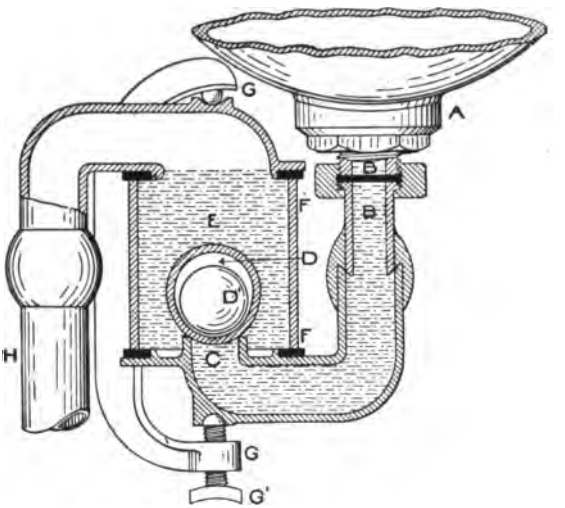


Fig. 17. Trap with Combined Water-Seal and Gravity-Acting Mechanical Seal.

It would be impossible here to consider the whole list of traps individually in an adequate manner. What has been said should be enough to enable one by careful study to decide each case intelligently upon its merits. Many special traps are deserving of more favor than is generally shown them. It is perhaps the fear on the part of the users of these articles of seeming to indorse the horde of cheap competitive articles that causes many to ignore alike the good and bad. This fear is well grounded. The wolves will creep in if the door is opened at all.

BATH FIXTURES

BATHTUBS

Classification. Bathtubs are a prime factor in plumbing and are made of various materials; they range in length from 4 to 6 feet, and the general shapes are the American, French, and Roman. The American pattern has a rounded bottom, one sloping end and one straight end. The French style has a flat bottom, one sloping end and one straight end. The Roman design has a flat bottom and two sloping ends.

The rims of bathtubs vary from 1½ to 5 inches in width. The larger rims are easy on one in getting in and out of the bath and are often used in lieu of a bath seat.

At one time, bathtubs were made of slate; wooden case lined with lead, zinc, copper, or sheet iron; cast iron painted; stoneware; and marble; but practically all modern tubs are made of cast iron, enameled, with a vitreous glaze fused on the iron; or of solid porcelain, potter's clay properly fired, with a vitreous glaze fired on.

Desirable Features for Bathtubs. The following points should be observed in selecting a bathtub:

It should be made of suitable material.

It should have provision for both filling and emptying rapidly.

It should be an adequate size.

It should be so constructed that all wooden or other casing is dispensed with.

It must have an overflow capable of carrying away the water obtained from both faucets.

All bath wastes must be trapped and vented and the size of the pipes should never be less than 1½ inches. The trap should be placed as close to the fitting as practicable, and provision should be made for cleaning the trap. In many localities, a drum trap provided with a trap screw 4 inches in diameter must be in full view above the floor and vented through a Y or similar fitting, is given preference over the floor or running trap.

Discussion of Types of Bathtubs. The most modern form of the American pattern cast-iron enameled bathtub with waste, overflow, and water supply connections is shown in Fig. 18. The very latest improvement, and one which has come to stay, is the

integral base which does not allow a particle of dust to find its way under the tub.

A fine enameled iron bathtub on the Roman pattern is shown in Fig. 19. It is provided also with integral base and can

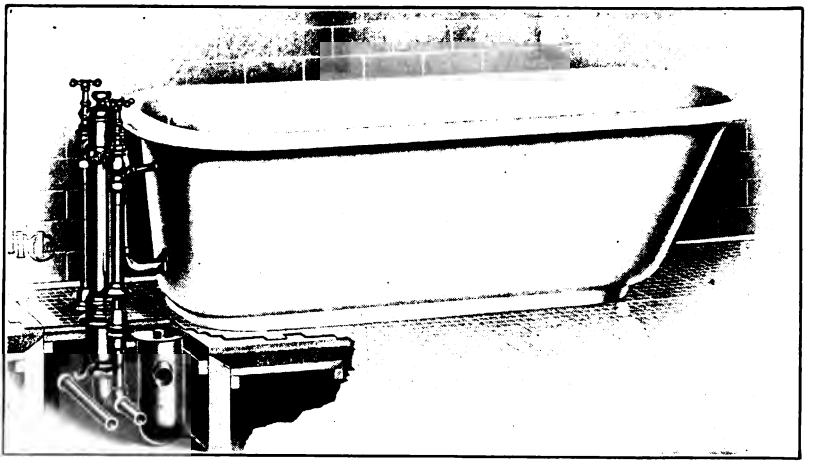


Fig. 18. Enameled-Iron Bathtub with Floor Cut Away to Show Waste, Overflow, and Supply
Courtesy of Federal-Huber Company, Chicago

be placed in either the right or left corner or free from all walls; but the best position, everything considered, is with the fitting side near the wall and not against either end of the room.

Fig. 19. Enameled-Iron Bathtub with Four-Inch Roll Rim. Fixtures Located in Center of Wall Side
Courtesy of Crane Company, Chicago

The solid porcelain tubs are ideal from a sanitary point of view, yet they are very heavy, averaging 1200 pounds each, and occasionally the floor is not capable of supporting them. Further-

more, the porcelain absorbs a tremendous amount of heat, and an efficient domestic hot-water supply must be installed, otherwise the tubs feel cold to the body and the water cools rapidly. These tubs are capable of withstanding considerable rough treatment and can be recommended highly for hotels and public institutions.

The last word in bathtubs from a sanitary standpoint is illustrated in Fig. 20, and embraces every modern feature, being provided with integral base, glazed inside and outside, and made to tile into the walls 1½ inches at the back and both ends. It is made in solid porcelain or porcelain enameled cast iron, and the following are the approximate measurements: length, 5 feet, 5 feet

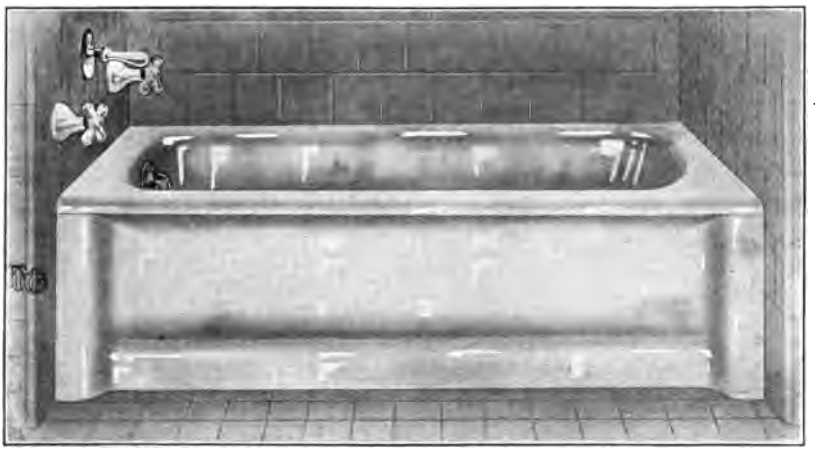


Fig. 20. Set-In Bathtub with Integral Base—Very Modern Equipment
Courtesy of Federal-Huber Company, Chicago

6 inches, or 6 feet; width over all, 30 inches; inside depth, 19 inches; height from floor to top of rim, 21 inches.

SPECIAL BATHS

Shower Baths. At one time, shower or rain baths were used principally in barracks, gymnasiums, schools, etc., but now the public demands both the shower and spray in the toilet rooms.

Many medical men advocate the action of jets or streams of water as the most hygienic method of bathing, for the impact results in stimulating the proper action of the skin and the body does not collect the soap and dirt floating on the surface of the water.

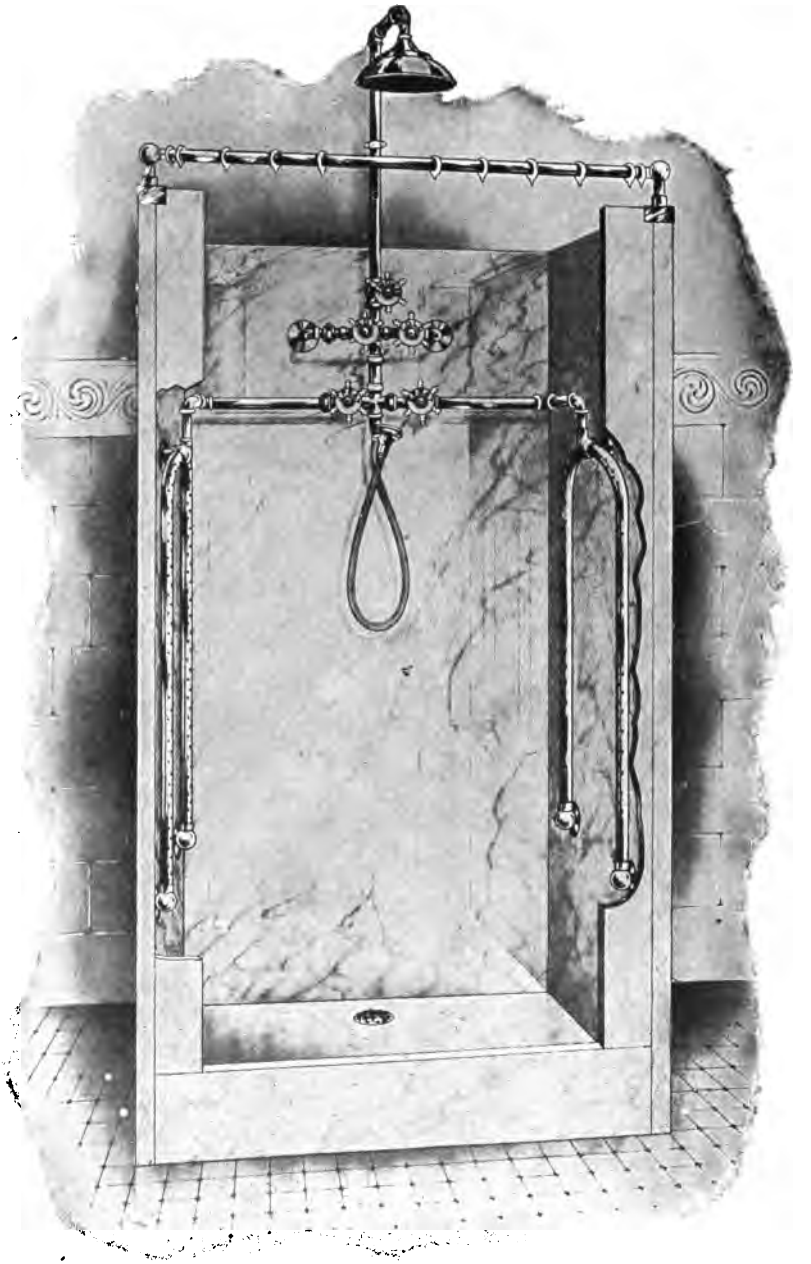


Fig. 21. Nickel-Plated Brass Shower Bath with Slate Cabinet
Courtesy of Federal-Huber Company, Chicago

The older form of showers which direct the water vertically upon the head of the bather are not so desirable as those in which the outlet is inclined and placed at about the level of the shoulders, thus avoiding wetting the head unless desired. Indeed, all the essentials of a bath of this kind are met by a water-supplied rubber tube discharging at about the level of the waist over a tight floor or pan provided with a drain.

Showers, sprays, and rubber hose suitable for attaching to the bathtub faucets can be purchased for about $1.00 in any plumbing or hardware store, while the most elegant shower with mixing

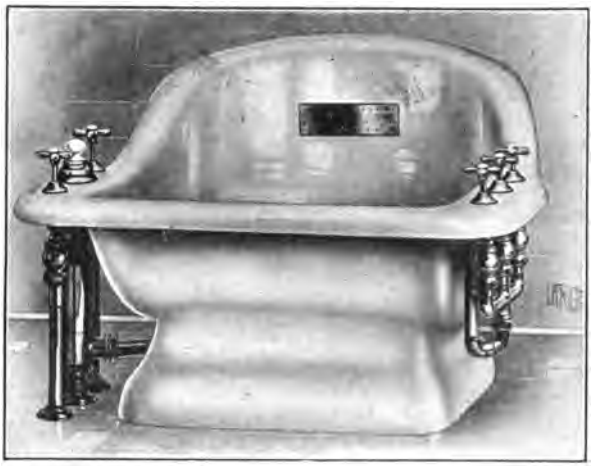


Fig. 22. Typical Sitz Bath
Courtesy of Federal-Huber Company, Chicago

valve, douche, needle spray, rose spray, and shampoo attachment, Fig. 21, can be purchased for $230.00.

A point concerning shower fixtures and relating to the safety of the user, to which special attention should always be given, is that of the valve arrangement. An adequate mixing valve is an essential part of the shower, especially so with the elaborate combinations, otherwise one is liable, inadvertently, to scald himself at first by turning on the hot water alone.

Sitz Baths. Sitz baths are primarily for bathing the hips and loins in a sitting posture but may be fitted with special features if so ordered. Solid porcelain and enameled iron are the usual

materials of construction. The fixtures approximate in dimensions, 15 inches in height at the front, 26 inches at the back, and are about 30 inches wide. In the back, at a proper height, is a horizontal slit accommodation fitting for a liver spray, a wide wave-like spray of water, either hot, cold, or of intermediate temperature, as suits the individual. Fig. 22 shows the latest type of sitz bath with integral base, 3-inch roll rim, china indexed handles, etc., while in the bottom, in conjunction with the outlet, is a hot and cold douche under control of the user. In the center of the douche, and operated independently, is a bidet jet, making the fixture exceedingly useful.

Fig. 23. Porcelain Foot Bath with Standard Fittings
Courtesy of Federal-Huber Company, Chicago

Fig. 24. Typical Baby Bath
Courtesy of Crane Company, Chicago

Foot Baths. An ordinary sitz bath can be used conveniently for a foot bath, but where there is no demand for such a bath,

a porcelain or porcelain enameled iron foot bath with integral base and 2½-inch roll rim, Fig. 23, can be installed. The approximate size of the foot bath, length over all, is 25 inches; width over rim, 21 inches; depth inside, 10 inches; and from floor to top of rim, 13 inches.

Baby Baths. Before leaving this branch of the work, it may be advisable to mention the "baby bath", Fig. 24. It is needless to say that only the wealthy can afford such a luxury, and there is no special demand for them. However, they are most convenient for the nurse as they fill and empty rapidly and are economical in the use of water.

WATER CLOSETS

Essential Features. The last few years have brought about some wonderful improvements in the style and construction of water closets. Comparing our present water closets with those of the pan and hopper types installed a few years ago, encased in woodwork and forming a chamber in which foul matter collected and developed, we find we have almost reached the acme of perfection. Nevertheless, all manufacturers of sanitary fixtures are constantly endeavoring to improve their product.

There are several points to be observed in selecting a suitable closet, which are as follows:

It must be constructed of a nonabsorbent and noncorrosive material.

It must have a small surface area, as this is always likely to become foul.

The basin should contain a large quantity of water.

It must have a good trap and a good depth of water seal.

The back should be as near vertical as practicable to obviate fouling.

It must be provided with a good flushing rim which will direct the water in such a manner that it will thoroughly cleanse the interior surface of the bowl and carry the excremental matter through the trap and into the soil pipe.

It must be constructed on the open or independent principle and fixed free from all casings or coverings.

Types of Water Closets. Types of water closets are innumerable and are separable into classes according to the principles of

action. Porcelain and painted or enameled iron are the materials used. Porcelain is more fragile, but has the better finish, and is susceptible of a greater variety of design and ornamentation. The all-vitreous body of water-closet china of today is far superior to the glazed clay ware of the past, which, depending only on surface impermeability, soon cracked badly, thus permitting absorption, the forerunner of odors which no plumber's skill could prevent. Enameled iron has not so durable a surface, but will stand rough usage, and has the advantage of very seldom cracking from frost even though the water in the trap freezes.

The greater relative advantage and durability of the porcelain closet over the best qualities of enameled-iron fixtures should not be overlooked. There is less adherence of the foul wastes to a porcelain surface than to the enameled surface. It is also a fact that enamel is subject more or less to abrasion by the use of harsh scouring materials, as well as to decomposition by uric acid and water-closet discharges, and is therefore not a very durable material. These statements can be confirmed by observation of closets which have been in use for a number of years.

Iron closets of the better forms are used most in public places, stores, warehouses, etc. The pan closet, of iron with earthenware bowl, is not now installed. For these, a trap was placed under the floor. The pan, operated by the same lever as the flushing valve, retained water, partially sealing the body from the bowl. The flush was by the swirling of a stream which entered tangentially under the rim. The bowls were round, as is necessary in all hopper closets thus washed, for water will not swirl in an oval bowl.

The objection to the pan water-closet is due principally to the fact that the outer bowl or container is a receptacle of filth which can never be cleansed properly. When the pan deposits its contents in the lower portion of the fixture, a considerable amount of the filth is spattered upon its inner walls and is not subject to the cleansing effect of the stream of water which scours only the upper bowl. When the closet is operated, the odors from this concealed surface permeate the room in an objectionable manner. The pneumatic form withdrew sewer air from between two traps and expelled it into the room through the bowl and was also expensive; it was therefore discarded. This objectionable feature

of construction is present in pneumatic range closets. The range, however, is rapidly losing favor and will shortly be discarded.

The pan and plunger forms of closets were seperseded because of their filthiness, although with them, flush and supply valves were brought to a high state of perfection; this is a benefit which the trade will always profit from by continued application of the principles, as is being done with time valves in various ways on direct flushing devices now in use and with ball cocks built on the principle of the old Jennings diaphragm valve.

A sectional view of the *combined hopper and trap pedestal* of today is shown in Fig. 25. It is made in one piece, in both porcelain and enameled iron. This form resulted from the separate hopper and trap fixtures before mentioned. The combined form has an oval bowl and integral flushing rim for tank supply.

The *wash-out* closet is a modification of the combined hopper and trap, being formed with a dipping bed under the mouth of the bowl, which retains enough water to keep soil from sticking to the surface. The water-bed makes it necessary to discharge the contents at either the front or rear of the bowl. The back-outlet wash-out is most repulsive to view; in them the drop-leg, which the flush never washes thoroughly, is always in view, so that its filthy condition suggests cleansing by hand. The front-outlet wash-out, shown in section in Fig. 26, is of more inviting appearance; but the drop-leg, although hidden, is there just the same. This type is rapidly becoming obsolete.

Both the wash-out and the combined hopper and trap types have one fault in common. The trap almost always contains the soil from one usage. When the contents of the trap are flushed out after using, sometimes a similar mass refills it. Of course, two or three consecutive flushes would leave comparatively clean water in the trap, but this is not to be expected in regular usage.

On certain occasions the wash-out may serve a useful purpose on account of the water-bed. The stools of children or the sick may thus be easily observed at the will of the physician or at the discretion of those in charge, while such is impossible where the soil is submerged at once.

Pneumatic siphon closets of various types have been put on the market. A good example of the type requiring two traps with an

air-space between, is shown in Fig. 27. A specially constructed flushing tank is connected with the air-space between the traps. The falling of the flush water creates a partial vacuum in the bottom compartment of the tank, which induces siphonage of the bowl contents.

In the effort to maintain a plenum in the flushing compartment of the tank while the flush water is flowing into the closet, the air between the traps is extracted, being drawn up through the air-pipe into the tank. Atmospheric pressure presses the water out of the bowl and upper trap when the pressure below it is sufficiently reduced. This water, added to the flushing water and that of the lower trap seal, which has been drawn above its normal level in response to the vacuum, is sufficient to form the long leg of an ordinary siphon; and thus both traps would be entirely emptied were it not for

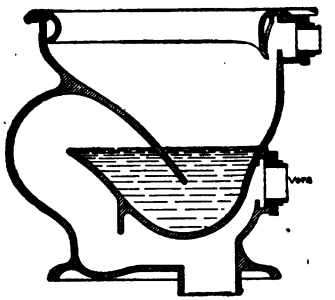


Fig. 26. Section of Combined Hopper and Trap Closet

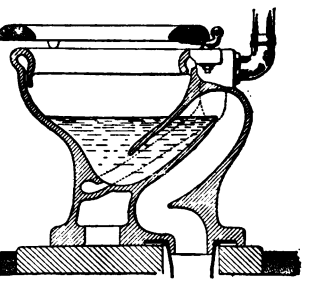


Fig. 25. Section of Front Outlet Wash-Out Closet

the vent in the crown of the lower trap breaking the siphonage in time to save a water seal for the lower trap.

The upper trap with water visible in the closet bowl in repose, is supplied by the *after-fill*, thus establishing conditions for the next action. The lower trap of such closets must be back-vented, and it is essential that the upper trap have no back vent.

The proper action of the tank is necessary to operate a pneumatic closet. A closet constructed on any other principle can be flushed with a bucket, by hand, if its tank is out of order. When a pneumatic closet gets contrary, pouring water into the bowl by hand simply fills or overflows it. The outlet is air-bound, and no passage of water to the soil pipe can take place until the barrier of air between the traps is removed.

The closets now accorded first place and generally used in the best work, are of the *Jet-Siphon* type, illustrated by the sectional view, Fig. 28. These use more water than is necessary to flush other kinds of closets, because a portion of the water is employed to produce the siphonage. A channel leading from the flush-water inlet to the bottom of the trap, conveys a stream of water to the trap leg, and injects it upward therein. The water in the channel has considerable velocity, and, being discharged into the water in the trap, imparts its energy to the whole mass, which, aided by the rise due to the incoming water from the flushing rim, moves upward at a proportionally slower but increasing speed depending on the ratio of mass and jet. When the water in the trap has been lifted in this way to an extent where sufficient of it can fall over the weir into the out-leg of the trap, a siphonic movement begins, and true siphonage finally takes place. Before the closet tank is emptied, siphonage sweeps out the trap thoroughly; and what water falls back into the bowl when the siphon breaks, together with the incoming jet and flush, often causes a second siphonage.

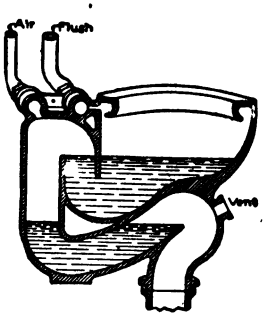


Fig. 27. Section of Pneumatic Siphon Closet, with Two Traps and Intervening Air-Space.

Accuracy in pointing the jet and in shaping the surfaces of its environment, are essential. If the surface above the jet-hole favors interference by the water flowing from the bowl, siphonage will be delayed and abortive, and may not take place at all. So, also, if the jet is not directed so as to maintain approximate concentricity in its travel through the mass of water, its energy is not expended to advantage, and failure is likely.

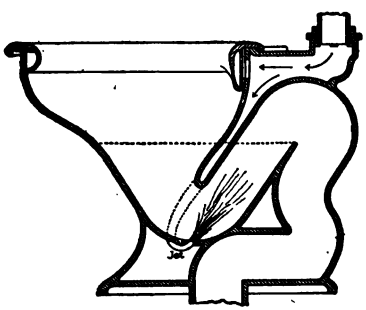


Fig. 28. Section of Jet-Siphon Closet.

There is no excuse for iron closets not siphoning perfectly. The iron pattern can be altered until it gives the best effect in practice, after which all closets cast from it should do the same. With porce-

lain ware, however, every closet made requires the same skill in design; and notwithstanding how perfectly the closet may be formed and the jet-hole cut, shrinkage in the kiln during the drying and burning process is apt to warp the wall and change the product so that it will not act properly. Closets of both materials, apparently perfect, often fail when first tried after installation, owing to foreign matter or fragments of enamel, clay, or iron lodging in the jet and changing its action. Usually these obstructions are easily removed by the plumber.

The jet principle has been added to the combined hopper and trap closet before mentioned, producing in it a siphonic action resulting in very much improved service over that of the simple form. With the jet-action, the combined hopper and trap is generally termed a *wash-down siphon.* The so-called "jet" is applied in two ways. In some makes, the flush rim has an extra large and specially formed fan-wash feature, which directs a sluice-like stream down the back wall of the bowl. This stream, in addition to wetting the paper and forcing it down into the water, where it will be promptly carried out, sweeps round the curve of the bowl outlet in such a way as to lend its force to the water in the trap to produce apparent and not infrequently true siphonage.

Another form of the wash-down siphon is provided with a channel from the flush inlet, down outside the back wall of the bowl, to near or even below the water level in the bowl, where the jet enters through a slit. The action is much the same as with the special fan-wash mentioned but is generally superior in siphonic effectiveness.

Jet-siphon closets are not provided with vent openings in the closet proper, except for the local bowl ventilation. Wash-out traps are, or should be, vented. The simple hopper and trap should be vented in the trap. Wash-down siphons, generally, are not vented; but it is permissible to vent them low down in the outlet leg of the trap.

The jetector wall closet, Figs. 29 and 30, wastes through the wall and does not rest upon the floor or depend on the wall or partition for its support. The closet is fastened directly to the soil stack by means of the screws *5*, *6*, *7*, and *8*, Fig. 29, and has been tested with a weight of 1800 pounds placed on the bowl without

any injury to the closet or hanger. It is undoubtedly the best sanitary closet on the market and is most economical in the use of water, a perfect flush being obtained with 2 to 3 gallons of water, as the action is direct.

It cannot clog except within easy reach of the hand, and any stoppage is readily removed. The flush is instantaneous; three-fourths of the water used follows the contents of the bowl, giving both the closet and soil stack a thorough scouring at every flush. The down draft also is instantaneous and removes local odors from the bowl at each flush, thus making it self-ventilating.

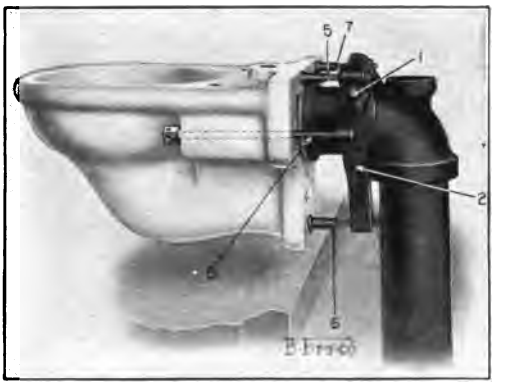


Fig. 29. Jetector Wall Closet, Showing Details of Support
Courtesy of Federal-Huber Company, Chicago

Frost-Proof Closets. Many eminent sanitarians who have experimented with frost-proof closets contend that it should be made a criminal offense to advertise them, for they are not sanitary. The length of pipe between the trap and the closet bowl is always foul, and oftentimes there is direct connection between the closet trap and the water supply pipe to the tank, which is most insanitary.

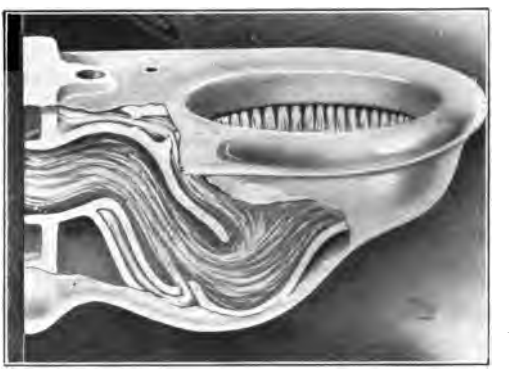


Fig. 30. Section of Jetector Closet
Courtesy of Federal-Huber Company, Chicago

The frost-proof closet in its present form has been evolved in good faith by certain manufacturers to protect closets from the destructive attack of ice formation during the winter months. In satisfactorily overcoming the danger the evolution of the apparatus seems to have been along lines which have not taken

into account sanitation laws already existing in many places and principles already known and established throughout the country governing the restrictions of fouling areas in sanitary apparatus.

Notwithstanding these logical contentions, frost-proof closets are now being used exten-

Fig. 31. Layout for Frost-Proof Closet with Galvanized-Iron Supply Tank

Fig. 32. Layout for Frost-Proof Closet without Supply Tank

Courtesy of Standard Sanitary Manufacturing Company, Pittsburgh, Pennsylvania

sively in outhouses and other exposed places. Although they cannot be considered the acme of sanitary perfection, owing to the large area exposed to fouling and the small area of water contained in the trap, no other form of closet will stand such locations

under like conditions and, being installed outside, adequate ventilation is always assured.

In the most approved types, the basins consist of an enameled cast-iron round hopper connected with a 4-inch cast-iron soil pipe which discharges into a trap about five feet below the level of the floor. The supply valve also is placed below the freezing depth and is operated by a pull or by seat action.

A typical frost-proof closet with galvanized-iron supply tank is shown in Fig. 31. The pressing down of the seat opens the supply valve and allows the water to flow into the tank. On rising from the seat, the supply valve closes and the water in the tank flushes the basin. After the flushing has taken place, the water remaining in the pipe above the valve drains off into the water-closet trap, through a small drain tube. When the fixture is not in use, there is no water standing in the flush tank or at any point in the piping above the supply valve. In Fig. 32 the flush tank is omitted, the closet being flushed direct from the supply pipe.

Closet Tanks. Closets are operated with pull or push-button tanks requiring the attention of the user and are also made of the seat-action type. Children are likely to be forgetful and visitors to public toilet rooms indifferent to such an extent that automatic closets are desirable for public places and schools.

Closets are fitted with two styles of tanks—one placed about 7 feet from the floor and serving with a flush pipe never more than $1\frac{1}{2}$ inches in diameter, and the other placed low down, as close to the bowl as connections will permit. Examples of the *high-tank* and *low-tank* arrangements are shown in Figs. 33 and 34, respectively. The low tanks are wider and deeper than the high style but do not extend out from the wall so much. The low position delivers the water at much less velocity than the elevated style and, to secure the utmost speed and the necessary volume, the flush connection is never less than 2 inches in a low-tank closet. The rim and jet channel are proportionately larger in bowls intended for use with low tanks. High tanks are about 17 by 9 by 10 inches. Sheet lead and sheet copper are used for closet tank linings. Some kinds of water, through galvanic action, attack the soldering of the seams in copper-lined tanks with more

effect than where lead alone is used. Generally, however, copper-lined tanks give satisfaction if the copper is heavy enough (12 to 16 oz.) and properly put in. Some makers lock-seam the linings water-tight, and solder on the outside before placing the copper in the wood case.

On account of the greater depth of low tanks, swelling of the wood case has, doubtless, been the cause of most of the trouble experienced with this type. When

Fig. 33. Modern High Tank Closet
Courtesy of Federal-Huber Company, Chicago

Fig. 34. Modern Low Tank Closet
Courtesy of The Trenton Potteries Company, Trenton, New Jersey

put together in the factory, the wood is very dry, and after being used for a short time, increases in height as a result of swelling from dampness. If the lining be tacked to the wood at bottom and top, injury is sure to result. Tacking at the top only is open to similar objections. It is now the practice to omit fastening the lining. Cast-iron tanks enameled two coats in and out give excellent service and so far have caused no trouble from sweating. Iron tanks with sheet metal interior lining have also proven satisfactory. Very great care has been found necessary with ball cocks for low tanks, in order to secure proper after-fill, the flush connection

being too short to aid much in resealing the bowl with its drainings. Low tanks flush with much less noise than high ones, and permit placing the closet under windows and low ceilings. Low ones require more width on account of the tank, and more depth from the wall to the front, as the seat and lid must be placed far enough forward to be thrown back and remain leaning against the front of the tank. Low tanks are provided with ventilated covers; while the high pattern which is out of children's reach, is left open at the top. The fewer working parts in a tank, the less likely it is to get out of order.

Fig. 35. Siphon-Jet Closet with Seat-Operating Pressure Tank
Courtesy of Crane Company, Chicago

A type of seat-action after-wash closet very seldom placed in private houses, is that with closed metal tank, as represented in Fig. 35. Depressing the seat opens a valve in the supply, and the water passes up through a flush pipe into a closed tank. The air in the tank is compressed until the air-pressure counterbalances that of the water. When the seat is released, the supply valve closes and a valve is opened, establishing communication between the closet and the tank. The compressed air then expels the water in the tank, flushing the closet just as a large supply with corresponding pressure would do without a tank. Closed-tank closets depend on pressure. The space occupied by the air in the tank is inversely proportional to the pressure; hence, even in heavy pressure, considerable of the tank's capacity is yet occupied by air when equilibrium is established; and the less the pressure, the smaller the amount of water it is possible to get into the tank. They are therefore not fit for very light pressures, though they sometimes serve well in the basement of a building where failure would be certain on the upper floor.

Condensation on single-shell sheet metal tanks is annoying. Open tanks of porcelain and iron are used more or less, but sweating is hard to overcome. Zinc paint and ground cork finishes have been employed with some satisfaction; and drip-cup collars discharging into the flush just under the tank on high-tank closets have served in this capacity, but nothing overcomes the sweating so well as a tight wood case. Insulated metal cases and double enameled cast tank, before mentioned, will prove the only serious rivals to the wood-case tank. Some makes of the pressure-tank closet require too much weight on the seat for successful operation by a child, and children would as a rule leave the seat too soon to allow the tank to fill reasonably well. The after-fill is accomplished by projecting the flush connection into the tank an inch or more, and drilling a hole $\frac{1}{4}$ inch or less in diameter through it near the bottom of tank. The rapid flow ceases when the water-level falls to the upper end of the inward-projecting flush connection, and the after-fill drains into the flush.

The flush fittings of an open tank consist essentially of a valve to admit water to the flush pipe; an overflow always open to the flush pipe; and a lever and connection, with chain and pull or button, to open the flush valve. A simple example of these is the siphon gooseneck, with flush-valve disc on one end and lever connection at the other. Prongs extend below the disc to guide and keep it in place. The overflow is through the gooseneck. Lifting the gooseneck an instant permits enough water to flow down the flush to start the siphon through it when the pull is released. The tank then siphons to the lower end of the gooseneck arm.

Where shortness of flush pipe or form of closet requires a decided after-fill, this is secured by special provision in the flush fittings, or by leading some of the supply delivered by the ball cock into the overflow.

The supply fittings of a closet tank consist merely of a ball cock of suitable form. For light pressure, simple leverage suffices. For heavy pressure, the inlet in the valve would have to be too small, or the ball too large and stem too long, for a small tank, if simple leverage were employed. Therefore compound-leverage cocks are usually substituted where the pressure contended with is over 30 pounds. There are ball cocks made in which the buoyancy of the ball merely operates a small secondary valve in a way to establish the initial

pressure over a disc of larger upper surface than that of the under side which covers the main water inlet of the cock. The disc is thus seated by the differential principle regardless of the pressure; and a 4-inch ball will close almost any size valve against any pressure.

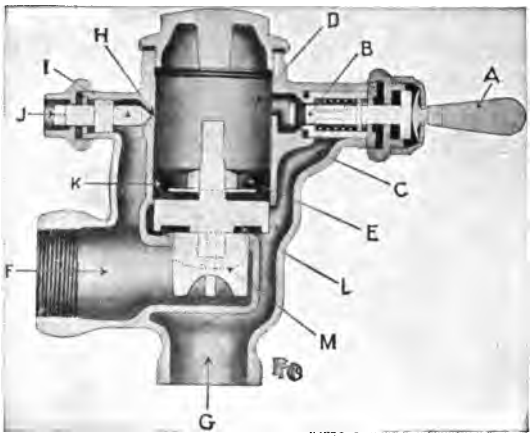
When the cock is attached through the bottom of the tank, no precaution against sound is necessary. When the cock is fitted in high up, a pipe from the delivery is extended to near the bottom of tank for the purpose of muffling the sound of the water as it fills the tank. An unmuffled delivery and a high-tank flush make considerable noise when the closet is flushed and are suggestive and very embarrassing to sensitive people. Silent action is therefore the goal for which many strive. Silence at the expense of thoroughly washing the closet surfaces and flushing out the contents, is not desirable; some noise is necessary to the rapidity of action essential to thorough scouring and evacuation.

Tanks requiring the flush valve to be held off the seat during the entire flush are now no longer installed. Perfect silence in the flush pipe of a high-tank closet has been obtained by a type of flush fitting that permits the pipe to hang full of water. The flush valve being opened, water begins to flow into the closet immediately. When the valve closes, no air having access at the upper end of the flush, the pipe remains filled. The flush valve of such a closet must close absolutely water-tight to prevent continual dribbling into the bowl.

Flushometers. Of late years, direct flushing valves or flushometers of many forms have been a feature of water-closet design. These valves make individual closet tanks unnecessary.

A section of a good type of flushometer is shown in Fig. 36A, in which the letters *A* to *M* represent the following: *A*—oscillating handle; *B*—release stem; *C*—by-pass; *D*—cylinder; *E*—piston; F—waterway to valve; *G*—waterway to closet; *H*—regulating by-pass; *I*—regulating screw; *J*—loose key; *K*—specially treated leather washer; *L*—encased leather seat washer; and *M*—refill disc.

The Boyle valve is of the balanced plunger type, that is, the piston is balanced so that the pressure of the water on the top will overcome the pressure at the bottom and close the valve. When the pressure at the top is removed, the pressure at the bottom



A

B

Fig. 36. Direct-Flushing Closet—Flushing Valve Shown in Section Above

Courtesy of Federal-Huber Company, Chicago

will raise the piston and open the valve. The piston is fitted with a specially treated leather washer which prevents the cylinder from being harmed by sand or other foreign matter. This washer can be replaced when necessary by removing the valve cap and lifting out the piston. It has only three moving parts: the handle, the release stem, and the piston.

Action. The action is as follows: When the oscillating handle *A* is pushed, it moves the release stem *B*, which allows the water in the cylinder *D* to run out through the by-pass *C*. This releases the pressure of the water on the top of the piston *E* and allows the water from the supply *F* to force it up and to run into the closet through the outlet *G*. While the water is running to the closet, a portion goes up the regulating by-pass *H* into the cylinder *D* where its pressure forces the piston *E* to close. The faster the water enters the cylinder *D* through the regulating by-pass *H* the quicker the valve will close, and *vice versa*. The length of the flush is controlled by the regulating screw *I* which is adjusted by a loose key at *J*. This permits the valve to be regulated from the outside without disturbing the interior. The supply to the valve should be as straight and with as few bends as possible. It should never be less than $1\frac{1}{4}$-inch iron pipe size and should be increased as conditions demand. The pressure of the water at the valve should be maintained at not less than 20 pounds per square inch. When a large number of water closets are installed in one building, it is best to supply the flushometers from a large tank installed for this purpose. From the tank, a proper size flush main is run direct to the closets, independent of the water supply or other fixtures. One tank with large flushing main will serve all the closets, and thus the individual tanks and equipment are not needed. Furthermore, no trouble is then experienced in providing suitable space for the small tanks. The valves may, if desired, be placed out of sight, and only the operating lever brought to view in a convenient position.

Range Closets. Batteries of individual closets are usual in office buildings and many other such structures; but in schools and in many public places open to all classes, ranges divided into stalls or compartments have been considered a satisfactory solution of the problem.

The objections to the range type of fixture are inherent in the design. The fouling surface of a trough fixture is much greater than that of the number of individual closets to which the fixture corresponds, and certain parts of this surface are not subject to an adequate flushing action. A certain portion of the surface, much larger relatively than that in individual fixtures, is exposed to spattering with the filth, and is alternately wet and dry. It is also true that the method of applying the water for scouring purposes is much less satisfactory than with single closets. A further objection to the range fixture is that in general its material is less desirable for the purpose than the earthenware or porcelain used for closets. On account of these deficiencies, for some ten years past, individual closets have been used in public schools in certain cities which have given the most attention to this branch of sanitation, and their use is being extended.

Range closets have automatic flushing tanks acting at any required interval between flushes. The tanks are, as a rule, without moving parts, and give good service without much attention after the supply is once set to flush at the interval desired. Whether the users of a closet are indifferent or irresponsible, does not change the result of abuse; and the range type of closet overcomes many annoyances attending the use of ordinary individual closets in unsuitable places—institutions for the insane and feeble-minded, for example. Ranges, like seat-action closets, are not dependent on the user, who may forget to pull a chain or push a button and thereby leave the closet foul.

Various forms of ranges are now operated on the siphon eduction principle. Siphonic eduction is accomplished in three ways—first, by the double trap and air-pipe to the tank indicated by the sectional view, Fig. 37, and operating exactly like the individual pneumatic closet already described; second, by a siphon outlet-end in which the water falls over a central weir that maintains the proper depth of water until the flush begins, and causes siphonage by breaking up and filling the channel as it passes through a constricted bend below. The latter method is shown in section in Fig. 38. Still another type of range is made to siphon by jet-action, just as the individual jet-siphon closet does, the trap providing a retaining weir which holds the water at the proper level in the range between flushes.

There are wash-out ranges with sloping weirs at the outlet to retain enough water to keep soil from sticking. These are open troughs, and the plumber provides the trap. Some siphon ranges are of the open-trough pattern, but the trap or the siphon outlet is a part of the fixture. All open-trough ranges can be supplied with a ventilating section from which a large vent pipe may be carried to a stack in which a draft is insured by a hot flue or some other means. Such ventilation changes the air in the room; and by having lids to all the seats, odors from the entire trough may be uniformly removed by

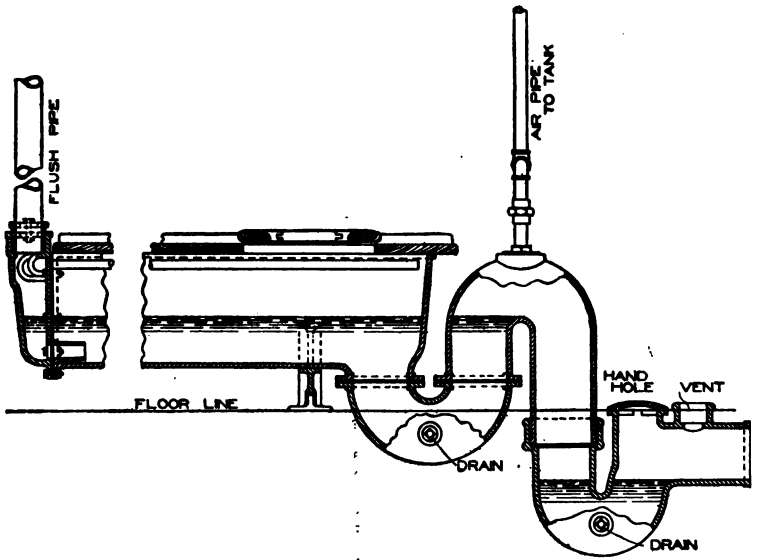


Fig. 37. Section of Range Closet, with Double Trap and with Air-Pipe to Tank to Cause Siphonic Eduction.

leaving up one lid only, at the end opposite the vent pipe. Some forms, having individual flushing-rim bowls cast integral with the section, are supplied by one general flush pipe, as indicated by the plan and elevation shown in Fig. 39. In these, each bowl is separately water-sealed, as the normal water-level is above the general conduit into which the bowls discharge.

Other forms, which receive the entire flush at one end, are water-sealed between the seat holes. The seat-openings, instead of converging like flushing-rim bowls, diverge downward, so that, as the water-level recedes in the sections during flushing, soil falls away from the surface by gravity instead of grinding against it. Therefore, so far

as cleanliness is concerned, the type with diverging surfaces but without the scouring effect of flowing water in the openings is, in operation, the practical equivalent of the flushing-rim type with converging surfaces. The open-trough ranges, including the jet-siphon type, have perforated wash-down pipes along the sides and ends, which, however, have little value. The open troughs are made in cast sections as long as convenient, joined by flanges with rubber gaskets and bolts. Suitable feet or chairs for supports are furnished with these fixtures.

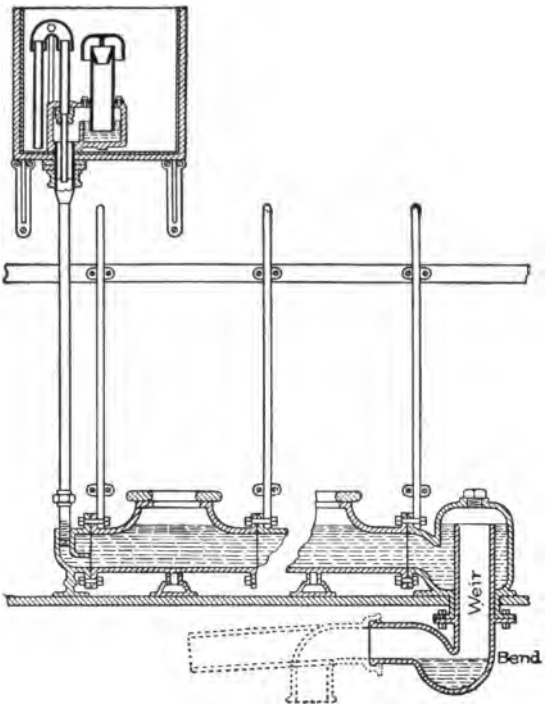


Fig. 38. Section of Range Closet, with Siphon-Outlet End.

Cast partitions, partitions and backs, and full compartment partitions, with slat doors and indicators, are furnished to order in any style or combination desired. For example, the range for a schoolroom may consist altogether of 24-inch sections or divisions, except one intended for the teachers' use made 30 inches and fitted with door and full-length partitions to give a thoroughly private compartment. Ranges are usually made of cast iron, and almost invariably finished with enameled interior and painted exterior. Bowl or section ventilation is provided for where possible. Wood seats and covers are generally used; but enameled-iron top frames with hinged seats and covers, and rigid enameled seats, are also made.

The lower trap of a double-trap range must be ventilated. All soil-pipe stacks into which ranges discharge, and fixtures connected

to them, must be well protected against siphonage, because the volume of water discharged at one time by a range is sufficient to siphon traps that ordinarily would retain their seals.

Urinals. Sectional urinals are made of the same materials and finish, and with much the same types of design, as range closets. They are generally installed in the same classes of buildings as range closets; but such urinals will often be found in the same toilet-room with individual closets. Roll-rim enameled troughs, with back and with simple perforated wash-down flush pipes on the back, are available. Solid porcelain stalls, are also in the market.

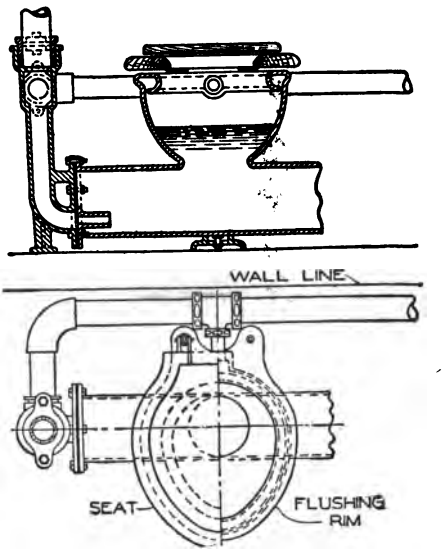


Fig. 39. Sectional Elevation and Plan of Range Closet Seat with Flushing-Rim Bowl Supplied from General Flush-Pipe

Single urinals are usually of porcelain, although some have been made of iron. Pedestal flushing rim urinals, resembling an extra

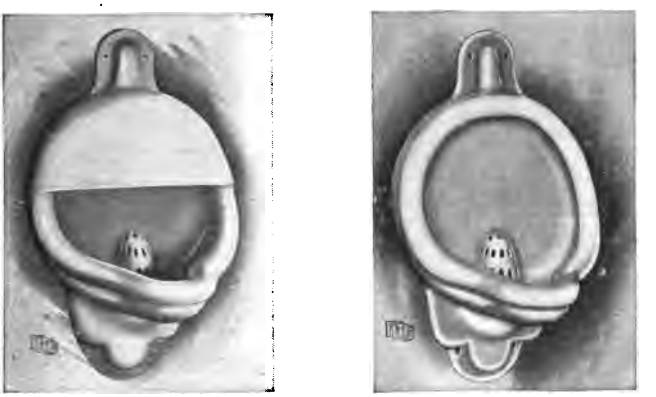


Fig. 40. Standard Types of Vitreous China Urinals
Courtesy of Federal-Huber Company, Chicago

tall water-closet bowl, are now regular market fixtures. The common types are plain or lipped, Fig. 40, made in flat-back and corner

designs. Direct-flushing valves of the same type as used on closets, adapted to the purpose, and cocks of various types, are the means of flushing generally provided for a single urinal. When two or more are placed in one toilet-room, an automatic tank with branched flush pipe is employed. These tanks are of greater variety than those used with range closets. The tilting bucket, pivoted within a tank case, which empties itself periodically by means of the flow of water changing the center of gravity to the unsupported side and tipping it just before it overflows, is a familiar type of automatic urinal-flushing tank. The standard tank with immovable parts, which siphons automatically, is the most prevalent. A section showing the "Watrous" automatic tank valve is given in Fig. 41.

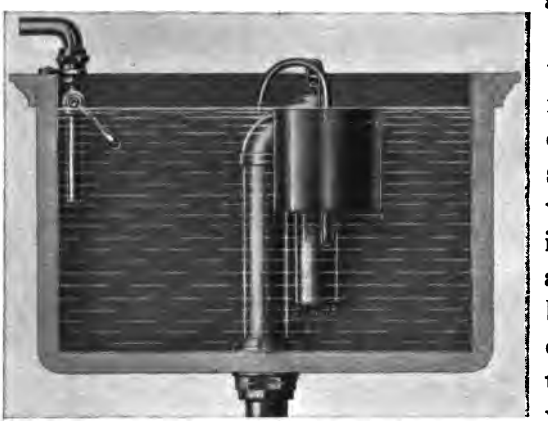


Fig. 41. "Watrous" Automatic Tank Valve
Courtesy of Federal-Huber Company, Chicago

Another design consists of a tank with common siphon, fitted with a ball cock which *opens*, instead of closing, as the water in the tank lifts the ball. The interval between flushes is governed by a small bibb cock. When water lifts the ball, the ball cock also admits water, the tank filling

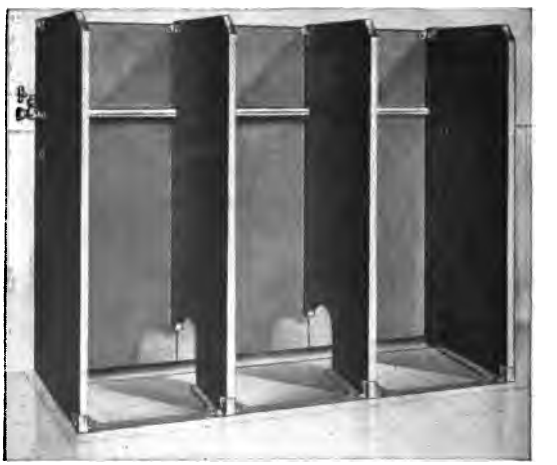


Fig. 42. Urinal Stalls of Slate, Flushed by Perforated Pipe, with Guttered Floor
Courtesy of Federal-Huber Company, Chicago

rapidly. The higher the ball is lifted, the faster the tank fills, so that by the time the water-level reaches a point where water begins to flow over the neck of the siphon, it is coming into the tank rapidly enough to more than keep pace with the overflow necessary to start the siphon. True siphonage, however, empties the tank much faster than the supply can fill it; and the tank is soon empty, leaving the small bibb cock to admit water again slowly to where this action can be repeated.

Individual urinals which siphon by admitting additional water to that which normally stands in the fixture, and various other types, will be best understood from a study of dealers' catalogues. In good work, marble backs and partitions usually enclose the urinals on three sides. Marble and slate stalls of various construction, with channeled and guttered floor, as shown in Fig. 42, all washed by perforated pipes fixed along the surfaces, are frequently used in lieu of specific urinal fixtures. A thick base of slab material is sometimes used, the gutter and drain-hole being cut in it. Cast-iron gutters, galvanized or enameled, with an outlet-end adapted to a soil-pipe connection are supplied by the makers.

MISCELLANEOUS FIXTURES

Drinking Fountains. Drinking fountains are now frequently used in stores, schools, and residences, the various fixtures adapted to such installations being readily obtainable. The basins or drip-slabs for public indoor fountains, are often cut to order by the manufacturer; and the cooling and faucet arrangements are provided by the plumber. Porcelain, enameled-iron, and marble fountains of stock designs are made. Most municipal regulations for schools require rough-like basins to be provided with sanitary drinking cups, Fig. 43, to prevent infection. The fixture shown in Fig. 44, consisting of solid porcelain, in which the drain-slab and the high back consitute a single piece, is of recent design, presents an excellent appearance, and has the advantage of being easily kept in immaculate condition. The two fountain drinking cups are built low to give a plentiful flow without spattering, and the compression cocks below are easy of manipulation.

One device, which serves well for common use, is the ordinary lavatory provided with a stiff perforated bottom fitting extending

well up toward the top of the bowl. This, with a proper faucet on the slab and a cup-chain fitted to the extra faucet-hole, makes a useful but not attractive fixture.

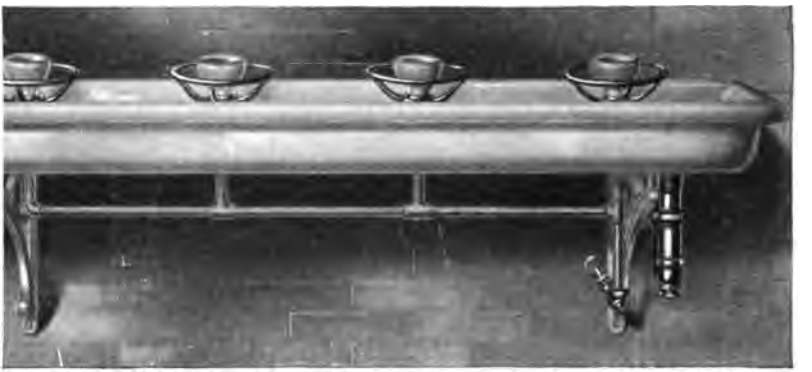


Fig. 43. Enameled-Iron Fountain Receptor with Self-Closing Heads Particularly Designed for Schools and Other Public Places
Courtesy of Crane Company, Chicago

Recessed porcelain and enameled fountains designed to be placed in wall niches and having concealed connections, as suggested by Fig. 45, are neat and require very little room outside the finished wall line. Countersunk slabs with strainer waste, with back either integral or separate as design or material dictates, are made in marble and porcelain. Marble fountains are adaptable to any location, because the slab and back can be cut to any shape or dimensions preferred. The fountain proper, faucet, cup, and waste-pipe connection with strainer, are all that is supplied by the makers.

Fig. 44. Double Vitreous China-Fountain with Integral Back and Separate Back Shield
Courtesy of Federal-Huber Company, Chicago

A type of fountain shown in Fig. 46, is provided with a flowing jet of water from which one can drink without placing the lips in contact with any metal surface. The small central bowl or cup is constantly sub-

merged and cleansed in the stream of water which passes outwardly over it, thus avoiding the danger incident to the common use of the same drinking cup by many persons. The surface does not afford lodgement to possible germs of disease which are most liable to transmit contagion when allowed to become dry and adhere to a surface. In fact, city ordinances require that all public drinking fountains be of the sanitary type.

Yard Fountains. Plumbers are rarely called upon to design the basin or attend to building the retaining walls of yard fountains or those built in parks and other public places, but they must be prepared to supply them with water and drain off the waste.

The basins are invariably circular. A conical bench is usually left in the center of the basin with sloping sides. The size of the bench or mound through which the supply rises is made to suit the fountain fixture. All sediment collects on the ring of low surface surrounding the bench and the waste pipe is brought through the bottom at the lowest point. The overflow enters at the bottom, but it may be entered higher up and on the waste pipe side if desired. The center is undoubtedly the best position for it, as the current to the overflow causes more sediment to collect on the overflow side and there is thus less chance of the drain being banked over when needed. The overflow should be protected by a netting to keep leaves and other rubbish out of the waste pipe. The drain should extend about two inches above the bottom so that a reasonable deposit of sediment will not interfere with its prompt action. A beehive strainer or netting should cover the outlet.

Suitable fountain fixtures may be found in catalogues. Such fixtures are numberless and range in price from a few dollars to almost any figure.

Lavatories. Lavatories are made from porcelain, enameled iron, marble, and onyx, in numerous patterns. The number of designs is so large that they are best understood if considered in the classes into which they may be divided. In marble and onyx fixtures, the slab, back, and bowl are necessarily separate pieces. In any but very accurate fitting and erecting, the unavoidable joints soon invite the accumulation of dirt, soapsuds, and other foul matter. Poor workmanship, settling, abortive countersinks, and faucet bosses not cut free within the countersink, have in many cases

brought slab types of basins into unjust repute, or, at least, have given basis for strong talking points against them, which have been effectively so used. If made and installed in the most approved manner, these styles, properly cared for, offer little

Fig. 45. Cast Bronze Recessed Drinking Fountain
Courtesy of Crane Company, Chicago

reason for severe criticism. One fact, however, must be borne in mind when comparing marble with other materials used for plumbing fixtures—namely, that marble is *not an impermeable stone.* Nearly all marbles (excepting only the very hardest and most dense) are quite absorbent, and depend upon the surface finish given to the

slab to resist the entrance of liquids into the body of the stone. As soon as the surface becomes roughened by wear, the greasy and acid wastes penetrate into the pores, and the marble becomes permanently discolored. Only a limited observation of the bad condition of marble floors or urinal slabs which have been subjected to use for a few years, is necessary to confirm this statement.

Ordinary Tennessee, Veined Italian, Hawkins County Tennessee, and Statuary Italian marble, range in cost in the order mentioned. Fancy imported marbles and onyx are much more expensive. Tennessee marble varies in color from grayish brown to very dark reddish brown, uniformly intermixed with light specks. The Hawkins County marble is bright reddish and white-mottled. All the ordinary materials are cut in stock sizes, and may also be had to order, like the more costly, in any size and shape desired. The type with apron or skirting, has legs, and the slab is supported by the skirting. When supported by brackets or leg-brackets, the strength of the slab is alone usually depended upon for support between the bearings. If brackets are properly spaced (as far from the ends as fittings will permit will never be too close together for any ordinary size), the weight is so balanced as to leave very little sagging strain on the slab.

Fig. 46. Enameled-Iron Fountain
Courtesy of Federal-Huber Company, Chicago

Built-in lavatories similar to Fig. 47 are often used and with appropriate fittings are very effective.

Porcelain and enameled-iron lavatories have bowl, back apron, and soap-cup in one piece. The pedestal of the lavatory illustrated in Fig. 48 is separate, of course, and no back is required, but the general features of integral construction are shown. The only injury possible to them is the marring or fracture of the glaze or enamel. Porcelain and iron lavatories, which can be furnished at reasonable cost, unlike those of marble, are adapted to pedestal support; and some very desirable patterns are therefore made in these materials only. Neither pedestal nor wall lavatories without backs, are suitable, except where the wall or wainscoting is of marble, tile, or other waterproof material.

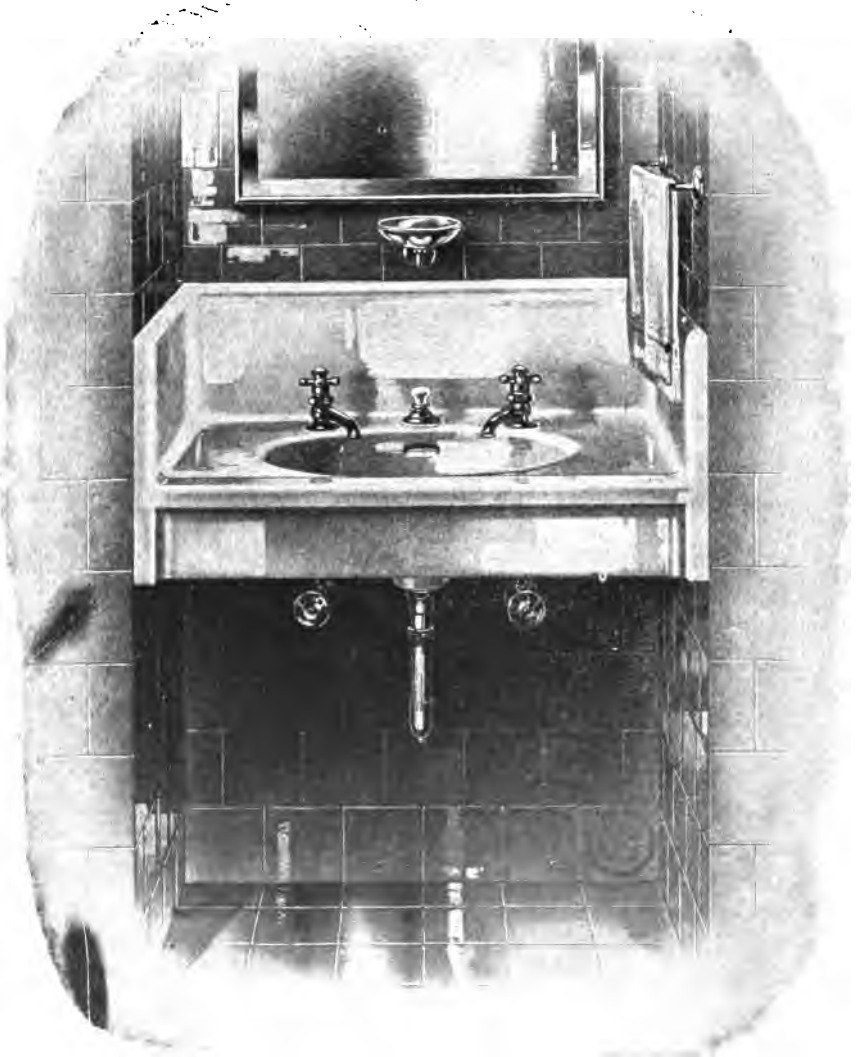


Fig. 47. Solid Porcelain Lavatory with Self-Closing Basin Faucets and Direct Lift Waste
Courtesy of Crane Company, Chicago

To provide for leaving the floor clear and free of obstruction, lavatories supported on brackets or hangers, as indicated in Fig. 49, with supply, waste, and ventilating pipes fitted on or into the wall, are best. If found practicable, a neater job results if all pipes leading to and from pedestal lavatories are carried through the pedestal. A supply and waste run to the floor is generally far easier and cheaper to secure than the fitting of all pipes to the wall.

The purchaser seeking iron or porcelain fixtures, has no choice of styles beyond that which the market regularly affords. If he prefers the workable materials, he should insist upon certain features of design which are essential to the best service. Abrupt edges and sharp corners should be avoided; the slab ought to be at least $1\frac{1}{2}$ inches thick, and the back not less than 12 inches high; the general dimensions must be as liberal as space will allow or the service demands (not less than 22 by 32 inches for a 14 by 17-inch bowl); the countersinking must be deep, $\frac{3}{16}$ to $\frac{1}{4}$ inch; the faucet bosses must not join the general border level at all; the faucets must not be less than 12 inches apart, nor so near the bowl that it will be difficult to secure them to the slab; nor may they be placed so close to the back as to make repairing troublesome with any type of Fuller faucets; the joint surface of the bowl must be ground to fit the slab, and provided with not less than four well-drilled anchor-holes for clamps to secure it.

Fig. 48. Lavatory on Pedestal
Courtesy of Federal-Huber Company, Chicago

Round bowls were formerly quite generally in use, but are now almost relegated to memory. The width of slab needed for a roomy, round bowl is too great; and at best the arms of the user must be cramped in a somewhat vertical and awkward position, while the smaller sizes are very uncomfortable in this respect. The sudden opening of the faucet when the bowl is empty, is likely to ricochet water with annoying results. This is caused by the water striking the curved bowl at a tangent; the action is not peculiar to the circular bowl; the oval or crescent, or, indeed, any shape of bowl that presents

a curved surface to which the faucet stream is tangent, favors the same result; the ovals in integral fixtures are the most annoying. Marble and onyx have an advantage over porcelain and enameled lavatories so far as ricocheting is concerned. The opening in the slab is not so large as the bowl, and thus a horizontal overhanging ledge is formed all around, above the bowl, which generally intercepts the water in a way to keep it off the floor and person. Porcelain and enameled fixtures have not this virtue. The bowl surface, being integral with the slab, is uninterrupted and continuous; hence ricocheting is more violent with them than is possible with the separate bowl.

Fig. 49. Vitreous China Lavatory with Integral Back
Courtesy of Trenton Potteries Company, Trenton, New Jersey

Oval bowls are now in general use on all types of lavatories. They employ slab space to the best advantage, and are the most convenient for use. The crescent or kidney shape, illustrated in Fig. 50, is, however, as far superior to the simple oval bowl as the oval is to the round. It permits the forearms to lie in a natural and most convenient position when dipping water to lave the face. This form of bowl should be accompanied with a scalloped or recessed front. The D-shaped bowl, and other bowls embracing the prime feature of the D-shape, while not so graceful in appearance, are, without exception, to be preferred, on the score of utter absence of ricocheting when the faucets are properly placed. The D-shape, a transverse section of which is shown in Fig. 51, has a semi-oval front, with the end lines continued parallel some distance past the major axis, and with a straight-line back nearly vertical. This form gives a nearly flat surface in the bottom between the back wall and major axis, on

which surface the stream strikes and breaks when the bowl is empty. A depth of water is quickly formed under the stream, which checks any spraying or spattering.

The traps used for lavatories are lead or brass (either cast or tubes), or combinations of these materials, plain or vented or of anti-siphon design. One trouble with lavatory trap ventilation, is the difficulty of obtaining a vertical rise directly above the trap. These vent connections should be carried as nearly vertical as possible, as high at least as the bottom of the lavatory slab, before any horizontal run is made; otherwise the choking of the waste pipe would float solid matters into places from which gravity would not dislodge them. In the absence of water-wash in the vent pipe, these solids would obstruct the vent and defeat its purpose. This danger is not given due attention by many plumbers. The patent and horn overflow bowls, with plug and chain, are the cheapest effective means of controlling the overflow and waste from the bowl. The standing waste, of essentially the same design as the waste fitting for a bathtub, with the body fitting projecting through the slab at the rear of the bowl, is perhaps the most satisfactory waste and overflow arrangement. Various schemes for operating basin stoppers by means of levers and swivels, are employed; but none of them has come into more than limited use.

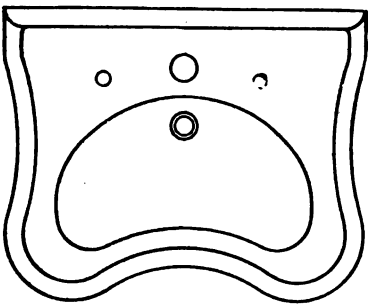


Fig. 50. Plan of Lavatory Slab with Crescent or Kidney-Shaped Bowl.

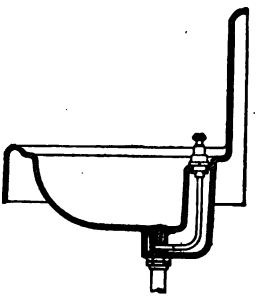


Fig. 51. Transverse Section of D-Shaped Lavatory Bowl.

Basin faucets, aside from special designs, are made on three general operating principles—(1) screw-compression; (2) eccentric action without springs; and (3) self-closing. They are also made in two types—with regular and low-down nozzles. All of these are represented in Fig. 52. The regular type has the nozzle some distance above the base flange, and screws into, or is cast on, the body. The low-down type has its nozzle with a flat bottom, hugging the slab as

closely as practicable. The objection to the low-down is the inaccessible narrow space between the nozzle and slab, which becomes filthy and is difficult to clean. High, projecting nozzles obstruct the space over the bowl, especially when washing the hair, but are otherwise most satisfactory. The high nozzle gives trouble with patterns of faucets that separate in the body for repairs, such as the Fuller type, which closes rapidly with pressure. The fault, however, is often that the slab is so shallow as to necessitate the faucets being placed too close to the back to turn without removing the nozzles. If these are cast on, removal of the whole faucet is required before it can be separated. Some faucets are made with union joint in the body, thus avoiding such trouble; but these are not widely used.

The false economy which often dictates the purchase of a small slab, generally also prevails in the selection of its trimmings. Compression faucets close against the pressure, and are slow in action, causing practically no reaction. They are generally responsible for the omission of air-chambers on supplies of medium pressure. On account of their slow action, they are suitable for high pressures although but little weight is given this fact by the trade. The features essential to good, lasting service in the compression faucet, are: a cross-handle, a stuffing box, a raised seat, and a swivel disc. Self-closing faucets of various patterns are made with a view to preventing waste of water, the intention being to compel the user to hold the faucet open only as long as water is needed, and to insure automatic closing when it is released. There are none such except the crown-handled, that an ingenious person cannot find means to hold open at will; yet, withal, self-closing faucets are of great value in reducing wastage. A rabbit-eared faucet can be kept open by placing a ring over the handles while squeezed together; the telegraph bibb, by weighting down or tying up the lever; and the T-handled, while not so easily controlled, can be tied open by a lever secured to the handle. The crown-handled design can be operated with ease by the hand of the user, but does not readily lend itself to unauthorized control by means of a mechanical stop. Self-closing faucets require strong and well-designed springs to close them against the force of the water. They have sometimes come into disrepute through leakage for lack of adequacy in this feature of their construction.

Lavatory supports should have positive means of leveling the slab, such as set screws, screw-dowels, or whatever adjustment the kind of lavatory and support may be best suited to. Lavatory brackets are generally at fault in having limited bearing at the bottom of the wall-face. This point of the bracket is where all the strain is thrown against the wall, and the effect is noticeable if the upper end springs away ever so little. Full-length brackets are not open to this criticism, but they interfere with the washboard or other finish next the floor.

Sinks. These are made in four general classes according to the purpose to be served—namely, Kitchen, Pantry, Slop, and Factory or Wash-Sinks. The materials used are:—Porcelain; enameled,

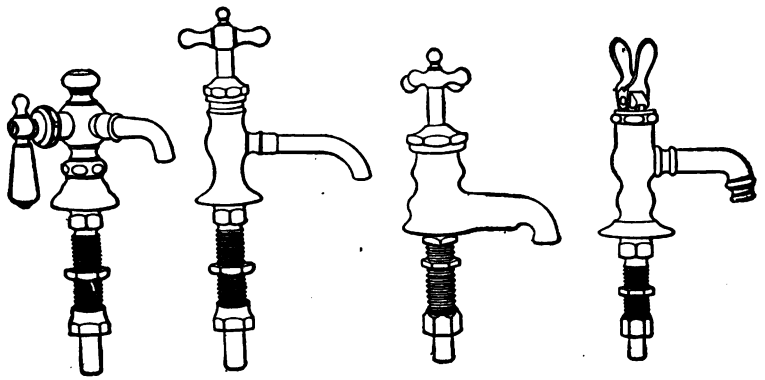


Fig. 52. Common Types of Basin Faucets

galvanized, and painted cast iron; enameled, galvanized, and painted wrought iron; brown glazed ware; copper; slate; soapstone; various compositions; and occasionally wood. Porcelain and enameled cast iron are most used, galvanized and painted sinks being confined principally to factory use. Sinks of extreme length, in one piece, or sectional, 6 to 8 inches deep, as shown in Fig. 53, with supply and faucets over the center line or at the side, belong to the factory class. There are roll-rim patterns, with bracket support and iron back, and with faucets fitted through the back. These are generally 8 inches deep and about 20 inches wide. The installation shown in Fig. 53 is particularly good on account of the skeleton character as it will collect little dirt.

Kitchen sinks vary in size according to general requirements. Common sizes are 18 by 30 inches and 20 by 30 inches. The depth

ranges from 6 to 7 inches. There are two types of iron sink—flat rim, with outlet at end; and roll-rim, with outlet in center. Neither style of outlet is always desirable as to connection; but the center outlet drains more directly. The flat-rim is not provided with legs. Cast legs were formerly furnished, being attached to the sink by slipping into dovetails. When legs are desired for this type, the plumber provides gas-pipe legs, with or without a top frame. Iron splash-backs are provided for flat-rim sinks, but not of the deep pattern in which air-chambers may be placed. Plumbers drill these sink rims to attach brackets or legs. and sometimes also to secure to them hardwood capping or drainboard. Hardwood drainboards are generally provided by the plumber's carpenter. Hardwood splash-backs, set free of the wall to permit circulation of air behind the fixture, are also provided. Sometimes marble splash-backs are provided. Marble is best, but is not in keeping with a flat-rim sink. The back may extend to the end of the drainboard, as represented in Fig. 54, or merely cover the length of the sink. Omitting the back behind the drainboard, is not often done. The drainboard should be free of the wall when the back is not extended. Iron sinks, with roll rim on front and ends, are furnished with drainboards suited to attach to either or both ends. These may be added as an after-consideration, or changed from side to side at will, if there is but one drainboard, or removed entirely, without marring the looks or service of the sink. This interchangeability commends itself to both plumber and customer.

Fig. 53. Individual Factory Lavatories
Courtesy of The Trenton Potteries Company

Roll-rim sinks, with the end recessed to receive a drainboard, are also made, but in any subsequent change of location require setting in the original position, so far as the drain is concerned.

Open strainers are most frequently fitted to sinks, in which case the sink cannot be then used for washing dishes, but merely serves as a support for dishpans and other vessels and as a catch-all for drippings from the drainer. Hence the open-strainer sink must be large enough to accommodate suitable washpans, etc., while one fitted with a plug-strainer should be relatively small if it is designed to use the sink proper as a washpan. A new form of sink waste connection is now a feature of the better class of enameled sinks, in which the connection is made by means of a spud and coupling something like

Fig. 54. Roll Rim Enameled-Iron Kitchen Sink Supported on Brackets. Splash-Back Omitted behind Drainboard

the ordinary lavatory coupling. In it the strainer is held down in a way less likely to cause injury to the sink lining at the waste hole.

The use of wooden sinks in large installations, such as hotel kitchens and restaurants, is not unusual, the theory of their use being that less breakage of crockery occurs, by reason of the softness of the material. However, because of the objection to any porous material which retains moisture and is subject to decomposition, wood is never suitable for this use, though with copper-lining it is permissible.

Rubber mats are essential for both sinks and drainboards having

enameled or glazed surfaces, in order to avoid accidental injury to both the fixture and the articles cleansed. As a matter of fact, the average dwelling has but one sink, which serves both kitchen and pantry purposes. Dual service is not always satisfactory, however, as no sink can be well adapted to both uses for a large family.

Porcelain and iron sinks have generally been supplied with loose backs; but sinks of one piece—that is, with sink and back integral—are now obtainable. Sinks with integral apron or skirting all around, placed free of the wall, are suitable where the wall is waterproof.

Sinks are built from slabs of natural stone as desired, and may be with or without drainboard or skirting. They are generally provided with a high splash-back. These sinks are not limited to the patterns of a moulding room, and easily keep pace with the desires of the purchasers. Selection is confined to a choice of material.

In the use of any natural stone, such as slate or soapstone, for plumbing fixtures, and especially for sinks, it should not be forgotten that angles and rectangular corners are with difficulty maintained entirely free from deposit. Although the flat surface can be readily scoured, it is always difficult to clean the sharp angles and corners satisfactorily. The difficulty is increased by the fact that some plastic jointing material, such as putty or cement, must be used in putting together the fixture; small fragments of this material project into the angles and render the corners rough.

Air-chambers may be cast in iron sink-backs, or independent cast or pipe chambers fitted in the cavity. The ordinary sink-back is not well suited to the convenience of the plumber where supplies to any fixtures pass up behind the sink. The faucet-holes cannot be changed, and slots for pipe are not provided at the top edge. Sawing these gaps after the goods are enameled, leaves the fixture with an unfinished appearance. The proportion of shank to the handle of faucets of the Fuller pattern used on sink-backs, must be such that the handles will turn straight back.

A popular fixture of comparatively late design, adapted for small dwellings and now made in the cheaper materials, is the kitchen sink in combination with a single laundry tray, Fig. 55. In this, the drainboard serves as a cover for the tray when the sink is in use. Sinks have also been supplied in combinations with lavatories, one sink being placed in the center or at the end of a battery of lavatories.

A pantry sink, Fig. 56, should always be provided with a drainboard. It is a smaller fixture than the kitchen sink, and is nearly always of the plug-strainer and overflow type. Its faucets are generally of the high-nozzle barber-shop type, but of smaller capacity and better adapted to rinsing than are kitchen-sink faucets. Indeed, the pantry sink proper need not necessarily differ at all, unless in size from sinks used for other purposes. Every feature of its trimmings and setting is intended to best serve the butler's needs.

The waste matter from the butler's sink is not like that from the kitchen sink; hence the waste pipe is not necessarily so large, nor is a grease-trap so badly needed. Grease in considerable quantities finds its way into kitchen-sink waste pipes. It floats on the stream of waste water as it travels through the pipe, and, being always next the interior surface, either adheres thereto on contact, or by a reduction in temperature is chilled and congealed and thus clings to the pipe walls. Successive layers of grease are in this way accumulated, and the bore of the pipe is finally reduced so much that solid matter easily completes the stoppage. Forcing out, and then filling the pipe with boiling lye water, and again flushing with hot water, will usually remove most of the obstruction. Sometimes the lye loosens the grease in chunks, which clog the pipe seriously at the first favoring point, and the pipe must then be cleaned manually.

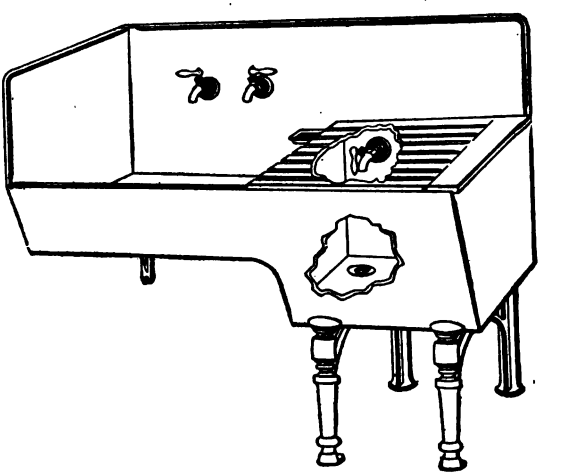


Fig. 55. Kitchen Sink and Single Laundry Tray Combined.

When once choked with grease, the pipe must ultimately be opened and cleaned by hand, often at material expense when long lines are deep underground. To avoid this trouble, various traps (of which two examples are shown in Fig. 57) have been designed to

separate and collect the grease, either by flotation alone or by chilling and flotation combined—generally by the former. The former were previously improvised by the plumber, being placed in the drainpipe just outside the building. This location left too much pipe subject to choking between the grease-trap and the sink; and the trap itself often became a generator of bad odors in warm weather.

The grease-traps now commonly furnished are placed in the kitchen under the sink, and frequently serve as the regular trap for the fixture. The grease is easily removed by lifting out the container or by skimming from the top. Hinged bolts with thumb-nuts secure the covers so that they can be easily and quickly opened and securely closed.

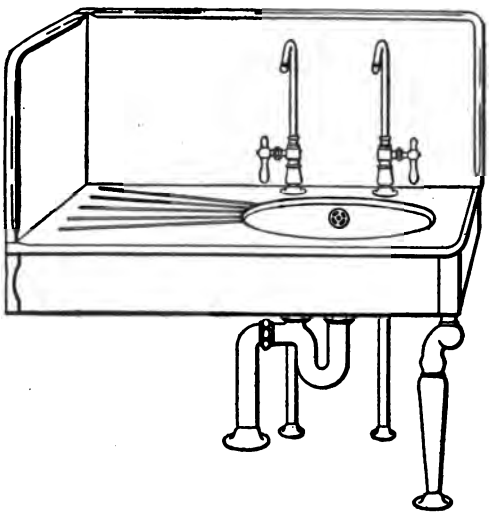


Fig. 56. Pantry Sink.

Traps which chill the grease are not used so much as those acting by simple flotation, but they do the work perfectly. The chilling process is accomplished by means of a water jacket through which the cold-water supply passes. The water entering low, surrounds the wall of the pot trap within, and passes out high up on the opposite side (see fixture at left in Fig. 57). Circulation—or, rather, change of water—in the jacket, is dependent on the amount of water used at the fixtures.

The usual slop sink is 18 by 22 inches and about 12 inches deep. Generally it is furnished mounted on a trap standard, as in Fig. 58, which serves the double purpose of support and waste-trap.

Care should be taken before installing a fixture placed upon a trap standard, to examine carefully whether the seal of the trap is provided for by suitable interior partitions. It is not uncommon to find defects in the casting, if of iron or brass—or in the porcelain, if of that material—which would seriously affect the maintenance of the

water seal. In fact, it is desirable in connection with slop sinks, as with all other fixtures, that the trap be of such a form as to show clearly, even after being set in place, the position of the various portions which constitute the trap and maintain the water seal.

The waste pipe for slop-sinks is never less in diameter than 2 inches, and is usually 3 or 4 inches. The outlet is invariably through an open strainer.

Slop sinks are made in all the materials common to other fixtures except natural stone. These sinks are to the chambermaid what the kitchen sink is to the cook. The shape and liberal-sized waste are well adapted to removing slop and scrub water. In the complete fixture, the sink is provided with an elevated tank and flushing rim

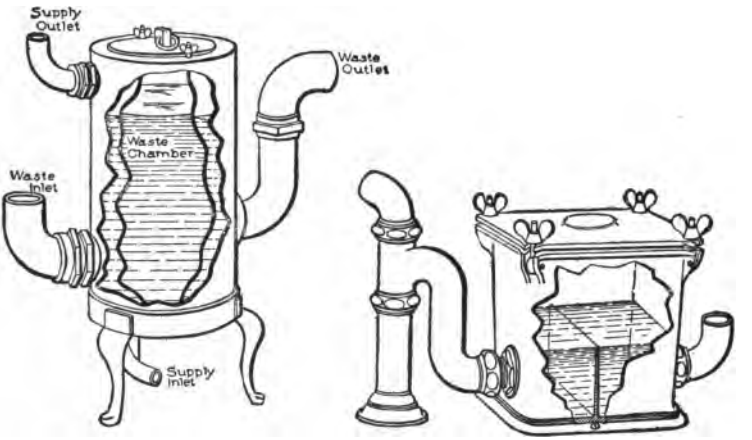


Fig. 57. Types of Kitchen Sink Traps for Separating and Collecting Grease.

to cleanse the fixture walls; also with hot and cold supplies for drawing water, rinsing mops, etc. The supplies are usually connected between the valves, and terminate with a long spout with pail-hook and brace. The spout supports the pail over the center of the sink while filling. The ordinary slop sink is provided with hot and cold faucets; and as the rims of the cheaper kinds are plain flanges, no tank flushing is possible.

Laundry Trays. These are made in all the materials used in other plumbing fixtures. Wood trays were formerly common but their unfitness because of absorption and odors, coupled with the increase in cost of lumber and the lessening in cost of the better materials, has effectually driven them out of the business.

The same inherent objection may be urged against the use of wood covers as obtains against that material for the body of the fixture.

Trays are made singly and otherwise, but generally used in sets of two or three, except in the combination with sink already described. They are supported by a center standard or a metal frame, as best suits the material used.

Fig. 58. Slop Sink Mounted on Trap Standard
Courtesy of Federal-Huber Company, Chicago

Some means of attaching wringers are provided, if possible. The waste is usually 2-inch. One trap answers for a set of trays. The size is about 26 by 30 inches at top and 15 inches deep. The walls are all nearly vertical except the front, which inclines about 30 degrees, making the width at bottom considerably less than at top. Some makers furnish one tray with each set, designed to serve as a washboard, the interior of the front wall being corrugated like the surface of a portable washboard. The inclination of the front is about right for scrubbing, whether the tray or an ordinary board is used, and the supports place the top of trays convenient to the work.

All trays were formerly made with faucet-holes in the back; and the plumber furnished a hinged cover. Side-handle faucets were necessary to allow the cover to close, as holes for top-handle faucets would be so low as to make useless too much of the space above them. The faucet-holes were seldom fitted water-tight. Holes are not now made in trays unless ordered, and the side-handle wash-tray bibb is disappearing. They were always annoying. If placed with the handles

right and left as intended, the seat could not be examined, and no reaming or dressing of the faucet seat could be done without removing the faucet. When placed with the faucet handles facing each other, they were wrong-handed and too close together. It was awkward to supply air-chambers—especially so when all the faucet holes were equidistant from the top. When placed for one line of supply above the other, one line of holes was too low. These objections combined brought about the practice of omitting the covers, putting the supplies over the trays, and using regular sink faucets. Overflows are provided only when so ordered.

Enameled backs with air-chambers and faucets are supplied with roll-rim enameled-iron trays. A complete set of three trays, with all

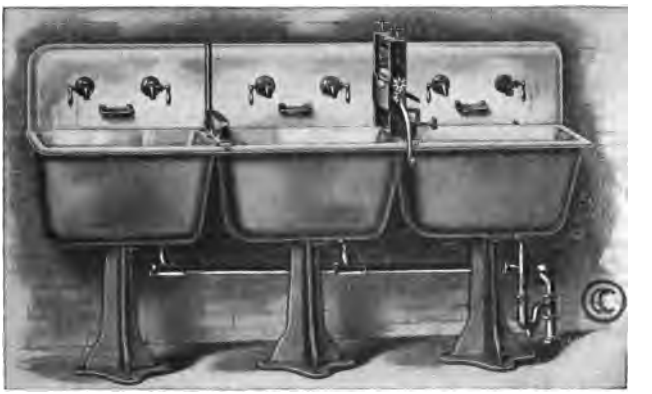
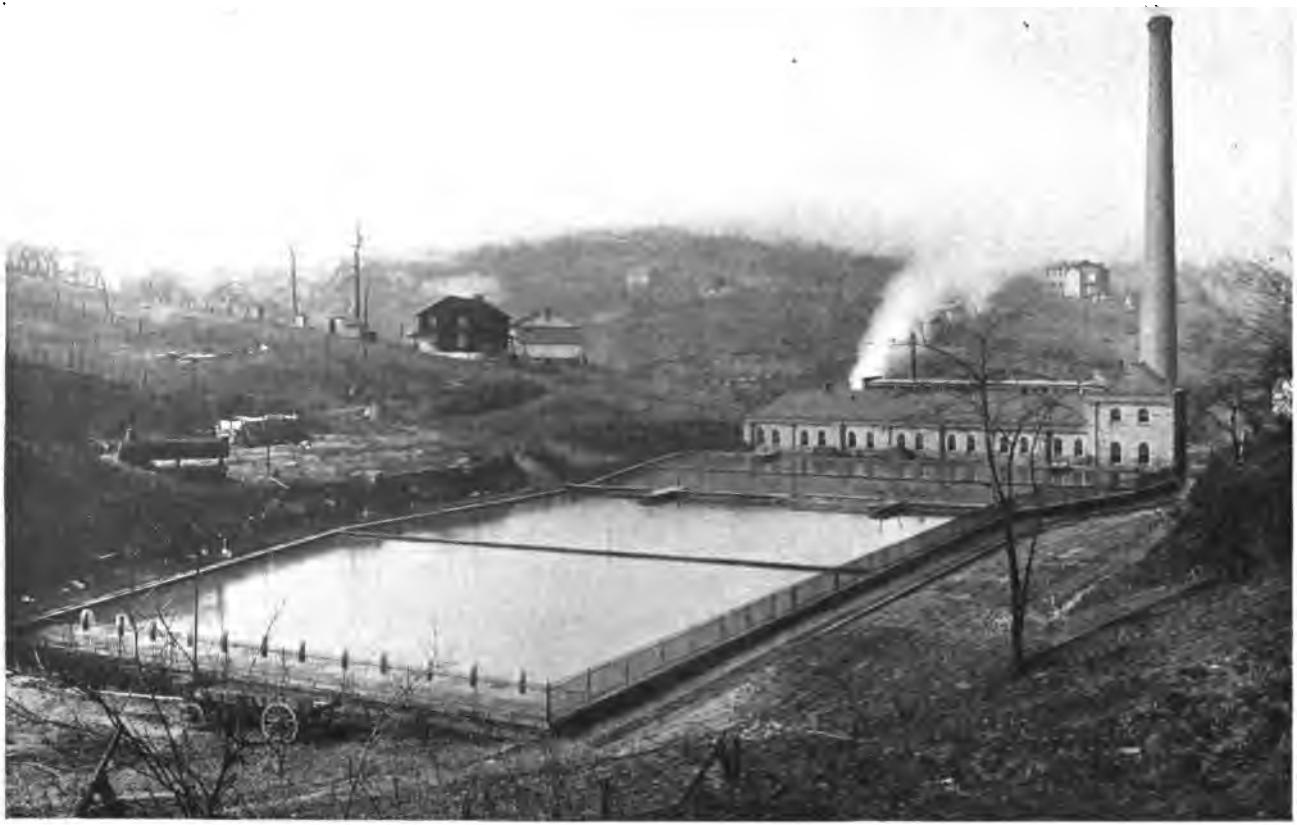


Fig. 59. Porcelain Enameled-Iron Laundry Trays with Fittings Complete
Courtesy of Crane Company, Chicago

attachments and fittings, is shown in Fig. 59. Flat-rim trays are made with or without faucet-holes, and are intended to have a hardwood frame to secure them rigidly. The wood frame and cover can be had with the fixture, but the plumber often supplies them. Nickel-plated or plain brass wastes and traps are furnished for trays, but the plumber can provide lead or cast-iron waste, if wanted.



VIEW OF SOUTH PITTSBURGH PUMPING STATION AND FILTER PLANT

Designed and Constructed by Mr. J. N. Chester, Civil Engineer, Pittsburgh, Pennsylvania

WATER SUPPLY

PART I

NATURE AND SOURCE OF WATER

Use of Water. Water is a prime necessity of life; without it, life can exist only in lowly organized beings and in them only in a dormant state. We need water for our food; for personal cleanliness; for domestic purposes such as washing, cooking, cleaning household utensils, floors, etc.; for cleaning drains, sewers, water closets, baths, lavatories, urinals, sinks, etc.; for extinguishing fires and watering streets; for horses and cattle; and for the various trade and manufacturing processes.

Composition. Water, when pure, is composed of two gases, hydrogen and oxygen in the proportion, by volume, of 2 parts hydrogen to 1 part oxygen; by percentage, 11 hydrogen and 88 oxygen; by weight, 2 hydrogen and 16 oxygen.

One cubic inch of water at 62° F. weighs 252.45 grains. The specific gravity is 1. Water is about 825 times as heavy as air. If two parts of hydrogen and one part of oxygen be exploded in a steel cylinder, with the aid of an electric spark, pure water will result.

Water may exist in three states, viz, solid (ice), liquid (water), and gaseous (steam).

Formation. We are entirely dependent on our rainfall for all natural sources of water supply. The heat from the sun evaporates surface water and water from the sea and carries it up into the air in the form of invisible vapor which forms into clouds. When these clouds become saturated, the moisture falls to the ground in the form of rain, snow, hail, or sleet, according to the temperature of the air through which it passes. When the rain or the snow reaches the earth, one-third is evaporated again and forms into more clouds; one-third flows over the surface of the earth and forms rivers, lakes, streams, etc.; and one-third percolates through the soil and forms underground sources of supply, such as springs, Artesian wells, shallow wells, etc.

Rainfall. The rainfall varies considerably in different localities and at different periods of the year. The maximum rainfall occurs along the North Pacific Coast where the average annual fall exceeds 64 inches. The minimum fall is found between the Sierra Nevada and the Rocky mountains and totals from 4 to 18 inches annually. The average annual rainfall throughout the United States may be taken as 40 inches. The average annual rainfall in Chicago is 34 inches; in New Orleans, 60 inches; in New York, 44 inches; in Yuma, 2 inches; in Vicksburg, 52 inches; in San Francisco, 23 inches; and in Denver, 13 inches.

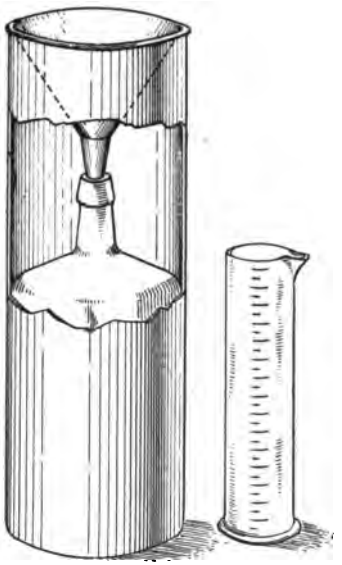


Fig. 1. Typical Rain Gauge

Rain Gauge. The rain gauge, Fig. 1, is an instrument in which the rainfall can be measured. It consists of a copper cylinder usually 18 inches in height and 6 inches in diameter. Inside this fits another cylinder provided with a funnel. To measure the rainfall, pour the contents into a graduated glass measure which is divided into $\frac{1}{10}$-inch and $\frac{1}{100}$-inch parts and holds $\frac{1}{2}$ inch of rainfall when full. If snow has fallen, it must be melted with a known quantity of hot water and then the added quantity deducted from the result. If the snow be heated over a fire, or the like, a quantity will be lost in evaporation.

Nature of Water. Rain water, strictly speaking, is distilled water and is water in its purest form. It is often called *soft water* and is the most useful kind for domestic purposes. However, in falling through the air, it gathers many impurities such as straw, carbon, small seeds, etc. Again, it washes the roofs of the buildings and gathers many more impurities as it comes down the rain leaders, rendering it quite unfit for many purposes in the house.

Water is spoken of as hard or soft according to its action on soap, and a rough test to ascertain the kind of water is known as the *soap test.* This consists of a standard soap solution added to the water. If the water is of a soft nature, it will lather freely, but should there be

any difficulty in obtaining a lather, the water is hard, and in this state the soap will only curdle and produce no lather until there is an excess of soap over the mineral salts in the water. This at once shows how wasteful it is for domestic purposes. If the rain falls on granite or on hard volcanic rocks, the water will be clear, sparkling, and soft, for it has no action on them; but if it falls on lime, chalk, or red sandstone rocks, the water will be hard. When it falls on peat, heather, or moorland district, the water will be soft but probably will contain a small per cent of humic acid which readily attacks lead and other metals. It will be dark in appearance and will contain a quantity of organic matter in suspension. When rain falls on a steep hillside, it usually flows off without percolating into the ground, and thus remains soft water.

The hard waters are divided usually into two classes, temporarily hard and permanently hard. Temporarily hard waters contain calcium carbonate, $CaCO_3$. Permanently hard waters contain calcium sulphate, $CaSO_4$, or gypsum. One grain of either $CaCO_3$ or $CaSO_4$ in one gallon of water is spoken of as 1 degree of hardness. Water is spoken of as soft water up to 6 degrees of hardness, and above 6 degrees, it is termed hard. The degree of hardness varies considerably throughout the United States and Canada, as much as 52 degrees of hardness being found in some localities, while only $1\frac{1}{2}$ degrees are found in others. In New York City the water has $2\frac{1}{2}$ degrees of hardness; in Chicago, 5 degrees; in Kansas City, 17 degrees; and in Los Angeles, 25 degrees.

Action on Metals. Soft waters readily attack lead, dissolve a portion of it, and carry it in solution. The waters which act most on lead are the purest and softest waters, especially when highly charged with oxygen, or those waters containing organic matter in large quantities. Besides the chemical character of the soft water, there are other conditions which aid the action of soft water on lead pipes. When the temperature is raised, the hot water has a more searching action on the lead than cold water, the action on new lead is greater than on old lead, and the pressure of the water in the pipes is also an aid to this action. Should this water be used, the consumers will doubtless suffer from the plumbisolvent action (lead poisoning). The symptoms are a blue line at the junction of the teeth and gums; violent pains in the bowels; colic; and palsy (wrist

drop). The smallest portion of lead dissolved in water—in fact, $\frac{1}{20}$ grain in a gallon of water—will cause the most serious illness, while $\frac{1}{10}$ grain per gallon means death. Soft water acts also upon iron and zinc, corroding iron so rapidly that water pipes are stopped up and iron tanks corroded through; and the water has so much suspended iron in it and is of such a color that it is rendered unfit even for washing clothes. Zinc is readily attacked by it, and consumers are likely to suffer from zinc poisoning. From this we learn that coating iron with zinc, known as galvanizing, is useless in soft-water districts. Copper, tin, slate, and porcelain are not affected by soft water. Hard waters have little action upon any metals, although in temporarily hard boiling water the lime is deposited in such quantities that the circulating pipes are filled up, which is a constant source of annoyance in hot-water apparatus. The quantity of lime deposited from one heater full of water would be so small as to be imperceptible in the ordinary way, but we must remember that in an ordinary house there may be eighty gallons of hot water used each day, and this quantity has all to pass through the boiler. Each day's supply is fresh and has its proportions of lime to add to that of yesterday until, in a few months, the collection becomes a formidable quantity. Sea water has practically no effect on lead but quickly dissolves zinc. Where iron is alternately wet and dry with sea water, it corrodes and, in some instances, becomes very soft and can be cut with an ordinary pocket knife.

APPROXIMATE DELIVERY

Factors Influencing Rate of Flow. While the plumber is likely to give more attention to supply pipe and to methods of installing it in buildings to secure specific service, *water supply* embraces also, in its broadest sense, the source and quality of water and the means of conveying it to the building. Plumbers generally have little dealing with the water supply outside of the house walls. Custom has fixed certain arbitrary sizes in ordinary work to such a degree that the average plumber has generally ignored information on the flow of water through pipes. Indeed, he is so rarely in actual need of this knowledge, that it appears a burden to acquire and to fix permanently in his mind the simplest formula bearing on the subject. Enough information to determine approximate deliveries and point the road

to further research, will not be out of place in behalf of those who may need simple directions.

The laws of gravity are the basis for the science of hydraulics, of which a prime factor of every problem is *velocity*. There is no exception to the rule that all bodies falling freely, descend at the same rate—in round numbers, 16 feet for the first second, at the end of which the acquired velocity is one of 32 feet a second. This is the basis on which are formulated the laws of falling bodies, which, exhibiting what is known as *velocity of efflux*, together with loss by friction, must be considered when calculating the flow of water.

There are three kinds of velocity—*uniform*, *accelerated*, and *retarded*. It is the last, and its cause, friction, that plumbers should be most interested in, as velocities calculated merely from the laws of falling bodies do not take account of friction, change of course, etc., which must be allowed for as causes diminishing the delivery of water through pipes. Briefly stated, the mysterious-looking Torricellian formula $\sqrt{2gh} = V$, means only that velocity is found by extracting the square root of the product of the head multiplied by 2×32, g standing for the force of gravity, and h for the height. For example, a stream filling a 1-inch pipe, with 25 feet head of water, would have a velocity calculated thus: $2 \times 32 \times 25 = 1{,}600$; and the square root of $1{,}600 = 40 =$ velocity, friction not considered.

The shape of the orifice through which water enters a pipe, has much to do with the amount of water that will enter it. Friction against the sides of the pipe, and change of direction due to bends and connections, occasion great variation from the theoretical flow. Not only is the character of the pipe surface and fittings to be considered as initial causes varying the delivery, but velocity, the all-important factor, must be reckoned with in every instance. With a velocity of 10 feet per second in a pipe of comparatively smooth interior surface, the friction loss in pounds on one square foot of surface will be about ½ pound. If this velocity is increased or diminished, the factor of friction will vary accordingly, always in proportion to the square of the velocity. Suppose the velocity to be 20 feet instead of 10 feet per second; we then have, 10 squared equals 100, and 20 squared equals 400. The square of these velocities is as 1 to 4, and as we assign a ½-pound loss to ten feet velocity per second, on a stated amount of surface, the friction due to doubling the velocity should be four times

a ½ pound = 2 pounds, showing that doubling the velocity increases the friction four-fold; trebling it increases friction nine-fold, etc.

A column of water weighs .43 pound per square inch of base, per vertical foot. Therefore a vertical pipe 100 feet high, with 1-inch sectional area, filled with water, would contain 43 pounds, and a gauge at the bottom would show 43 pounds pressure. If the pipe were only ¼ inch, or were 40 inches in diameter, the gauge would show the same pressure for the same vertical height—namely, .43 pound per square inch per vertical foot. A head of water expressed in feet, may be changed to pounds by multiplying the feet of head by .43. Pressure is made to read in feet of head by multiplying pressure per square inch by 2.3. A *head of water* is the number of vertical feet from level of source of supply to center of outlet or point of delivery.

Diameter of the pipe has nothing to do with static head or pressure; but its relation to the size of the orifice from which the water is to be drawn has much to do with the amount of pressure lost by friction. If a faucet and supply pipe are of equal capacity, and we *double* the size of the pipe, the velocity of the water flowing through it is reduced three-fourths; and the friction is, under these conditions, but one-sixteenth what it was in the original size. Moreover, as in drawing similar amounts of water under the same head through a one-inch and a two-inch pipe, the amount of friction surface presented is twice as great in the one-inch as in the two-inch pipe, the friction in the one-inch can be shown to be 32 times as much as in the two-inch pipe.

With the formula given above, one can roughly approximate by finding the theoretical delivery and deducting a liberal percentage for friction, according to size, length of pipe, and head or pressure. The subject, however, is vast and tedious, introducing intricate calculations in higher mathematics when considered in detail with a view to extreme accuracy of results, and is a branch properly belonging to hydrodynamics, rather than suited to presentation at length here. Two tables are given, however, which with the rules for use, will be of value to those who fail to make further research.

Table I shows the pressure of water in pounds per square inch for elevations varying in height from 1 to 135 feet.

Table II gives the drop in pressure due to friction in pipes of different diameters for varying rates of flow. The figures given

TABLE I

Head in feet	Pressure pounds per square inch	Head in feet	Pressure pounds per square inch	Head in feet	Pressure pounds per square inch
1	.43	46	19.92	91	39.42
2	.86	47	20.35	92	39.85
3	1.30	48	20.79	93	40.28
4	1.73	49	21.22	94	40.72
5	2.16	50	21.65	95	41.15
6	2.59	51	22.09	96	41.58
7	3.03	52	22.52	97	42.01
8	3.46	53	22.95	98	42.45
9	3.89	54	23.39	99	42.88
10	4 33	55	23.82	100	43.31
11	4.76	56	24.26	101	43.75
12	5.20	57	24.69	102	44.18
13	5.63	58	25.12	103	44.61
14	6.06	59	25.55	104	45.05
15	6.49	60	25.99	105	45.48
16	6.92	61	26.42	106	45.91
17	7.36	62	26.85	107	46.34
18	7.79	63	27.29	108	46.78
19	8.22	64	27.72	109	47.21
20	8.66	65	28.15	110	47.64
21	9.09	66	28.58	111	48.08
22	9.53	67	29.02	112	48.51
23	9.96	68	29.45	113	48.94
24	10.39	69	29.88	114	49.38
25	10.82	70	30.32	115	49.81
26	11.26	71	30.75	116	50.24
27	11.69	72	31.18	117	50.68
28	12.12	73	31.62	118	51.11
29	12.55	74	32.05	119	51.54
30	12.99	75	32.48	120	51.98
31	13.42	76	32.92	121	52.41
32	13.86	77	33.35	122	52.84
33	14.29	78	33.78	123	53.28
34	14.72	79	34.21	124	53.71
35	15.16	80	34.65	125	54.15
36	15.59	81	35.08	126	54.58
37	16.02	82	35.52	127	55.01
38	16.45	83	35.95	128	55.44
39	16.89	84	36.39	129	55.88
40	17.32	85	36.82	130	56.31
41	17.75	86	37.25	131	56.74
42	18.19	87	37.68	132	57.18
43	18.62	88	38.12	133	57.61
44	19.05	89	38.55	134	58.04
45	19.49	90	38.98	135	58.48

are for pipes 100 feet in height. The frictional resistance in smooth pipes having a constant flow of water through them is proportional to the length of pipe. That is, if the friction causes a drop in pressure of 4.07 pounds per square inch in a $1\frac{1}{4}$-inch pipe 100 feet long, which is discharging 20 gallons per minute, it will cause a drop of $4.07 \times 2 = 8.14$ pounds in a pipe 200 feet long; or $4.07 \div 2 = 2.03$ pounds in a pipe 50 feet long, acting under the same conditions. The factors given in the table are for pipes of smooth interior, like lead, brass, or wrought iron.

TABLE II

Friction Loss in lb. per sq. in., per 100 ft. of Clean Iron Pipe of Sizes Given, Together with Number Gallons Discharged per min., and Velocity of Flow of Water per sec.

Gallons Discharged (per min.)	Velocity (ft. per sec.)	Friction Loss (lb.)	Velocity (ft. per sec.)	Friction Loss (lb.)	Velocity (ft. per sec.)	Friction Loss (lb.)	Velocity (ft. per sec.)	Friction Loss (lb.)	Velocity (ft. per sec.)	Friction Loss (lb.)	Velocity (ft. per sec.)	Friction Loss (lb.)	Gals. Discharged (per min.)
	¾-in. Pipe		1-in. Pipe		1¼-in. Pipe		1½-in. Pipe		2-in. Pipe		2½-in. Pipe		
5	8.17	24.6	3.63	3.3	2.04	0.84	1.31	0.31	0.91	0.12	....	....	5
10	16.30	96.0	7.25	13.0	4.08	3.16	2.61	1.05	1.82	0.47	1.02	0.12	10
15	....	....	10.90	28.7	6.13	6.98	3.92	2.38	2.73	0.97	....	....	15
20	....	....	14.50	50.4	8.17	12.3	5.22	4.07	3.63	1.66	2.04	0.42	20
25	....	....	18.10	78.0	10.20	19.0	6.53	6.40	4.54	2.62	....	....	25
30	....	....	....	....	12.30	27.50	7.84	9.15	5.45	3.75	3.06	0.91	30
35	....	....	....	....	14.30	37.0	9.14	12.40	6.36	5.05	....	....	35
40	....	....	....	....	16.30	48.0	10.40	16.10	7.26	6.52	4.09	1.60	40
45	....	....	....	....	....	....	11.70	20.20	8.17	8.15	....	....	45
50	....	....	....	....	....	....	13.10	24.90	9.08	10.00	5.11	2.44	50
75	....	....	....	....	....	....	19.60	56.10	13.60	22.40	7.66	5.32	75
100	....	....	....	....	....	....	....	....	18.20	39.00	10.20	9.46	100
125	....	....	....	....	....	....	....	....	....	....	12.80	14.90	125
150	....	....	....	....	....	....	....	....	....	....	15.30	21.20	150
175	....	....	....	....	....	....	....	....	....	....	17.10	28.10	175
200	....	....	....	....	....	....	....	....	....	....	20.40	37.50	200
	2½-in. Pipe		3-in. Pipe		4-in. Pipe		6-in. Pipe		8-in. Pipe		10-in. Pipe		
25	1.63	0.21	1.13	0.10	....	....	....	....	....	....	....	....	25
50	3.26	0.81	2.27	0.35	1.28	0.09	....	....	....	....	....	....	50
75	4.90	1.80	3.40	0.74	....	....	....	....	....	....	....	....	75
100	6.53	3.20	4.54	1.31	2.55	0.33	1.13	0.05	....	....	....	....	100
125	8.16	4.89	5.67	1.99	....	....	....	....	....	....	....	....	125
150	9.80	7.00	6.81	2.85	3.83	0.69	1.70	0.10	....	....	....	....	150
175	11.40	9.46	7.94	3.85	....	....	....	....	....	....	....	....	175
200	13.10	12.47	9.08	5.02	5.11	1.22	2.27	0.17	....	....	....	....	200
250	16.30	19.66	11.30	7.76	6.39	1.89	2.84	0.26	1.59	0.07	1.02	0.03	250
300	19.60	28.06	13.60	11.20	7.66	2.66	3.40	0.37	....	....	....	....	300
350	....	....	15.90	15.20	8.94	3.65	3.97	0.50	....	....	....	....	350
400	....	....	18.20	19.50	10.20	4.73	4.54	0.65	....	....	....	....	400
450	....	....	20.40	25.00	11.50	6.01	5.11	0.81	....	....	....	....	450
500	....	....	22.70	30.80	12.80	7.43	5.67	0.98	3.19	0.25	2.04	0.09	500
750	....	....	....	....	....	....	8.51	2.21	4.79	0.53	3.06	0.18	750
1000	....	....	....	....	....	....	11.30	3.88	6.38	0.94	4.08	0.32	1000
1250	....	....	....	....	....	....	....	....	7.97	1.46	5.10	0.49	1250
1500	....	....	....	....	....	....	....	....	9.57	2.09	6.12	0.70	1500
1750	....	....	....	....	....	....	....	....	....	....	7.15	0.95	1750
2000	....	....	....	....	....	....	....	....	....	....	8.17	1.23	2000

The friction due to fittings is generally taken to equal straight additional pipe for each as follows: 90° ells, 40 diameters; pipe entering tee, 60 diameters; pipe entering coupling, 20 diameters, and, interposing a globe valve, 60 diameters.

Examples. A $1\frac{1}{2}$-inch pipe 100 feet long connected with a cistern is to discharge 35 gallons per minute. At what elevation above

the end of the pipe must the surface of the water in the cistern be to produce this flow?

In Table II we find the friction loss for a $1\frac{1}{2}$-inch pipe discharging 35 gallons per minute to be 5.05 pounds. In Table I we find a pressure of 5.2 pounds corresponds to a head of 12 feet, which is approximately the elevation required.

How many gallons will be discharged through a 2-inch pipe 100 feet long where the inlet is 22 feet above the outlet? In Table I we find a head of 22 feet corresponds to a pressure of 9.53 pounds. Then, looking in Table II, we find in the column of Friction Loss for a 2-inch pipe that a pressure of 9.46 corresponds to a discharge of 100 gallons per minute.

Tables I and II are commonly used together in examples.

A house requiring a maximum of 10 gallons of water per minute is to be supplied from a spring which is located 600 feet distant, and at an elevation of 50 feet above the point of discharge. What size of pipe will be required? From Table I we find an elevation or head of 50 feet will produce a pressure of 21.65 pounds per square inch. Then if the length of the pipe were only 100 feet, we should have a pressure of 21.65 pounds available to overcome the friction in the pipe, and could follow along the line corresponding to 10 gallons in Table II until we came to the friction loss corresponding most nearly to 21.65, and take the size of pipe corresponding. But as the length of the pipe is 600 feet, the friction loss will be six times that given in Table II for given sizes of pipe and rates of flow; hence we must divide 21.65 by 6 to obtain the available head to overcome friction, and look for this quantity in the table, $21.65 \div 6 = 3.61$, and Table II shows us that a 1-inch pipe will discharge 10 gallons per minute with a friction loss of 3.16 pounds, and this is the size we should use.

EXAMPLES FOR PRACTICE

1. What size pipe will discharge 40 gallons per minute, a distance of 50 feet, with a pressure head of 19 feet? Ans. $1\frac{1}{4}$-inch

2. What head will be required to discharge 100 gallons per minute through a $2\frac{1}{2}$-inch pipe 700 feet long? Ans. 52 feet

In calculating the contents of pipes, cylinders, and cisterns, where it is usual to correct the area found as a result of squaring the diameter by multiplying by .7854, before dividing by 231 for U. S.

gallons, multiplication by the decimal may be omitted, and dividing by 294 instead of 231 will then give the same result.

WATER SUPPLY SYSTEMS

There are various ways in which it may be necessary to obtain the water supply for a building. The usual course in cities and towns is to employ the Municipal Water Works service. This, of course, settles the supply feature, and the plumber simply provides the house and yard pipe, $\frac{3}{4}$-inch or larger main, according to the character of the work. If of lead, the pipe must be of strength according with the pressure. Any of the light-weight grades of lead supply will stand 1,000 pounds per square inch for a short time; and the usual strength used on 50- to 80-pound pressure will not burst under 1,400 to 1,600 pounds when new and unstrained. Under constant pressure, the enormous strain possible from water-hammer, and general deterioration from use, make it advisable to employ pipe which, when new, is 20 times as strong as that necessary to contain the pressure. No attention is necessary as to the strength of zinc-coated or tin-coated iron pipe; it will stand any pressure ordinarily encountered.

The two general methods of supplying buildings with water are: (1) the *direct* system; and (2) the *indirect* or *tank* system. The direct method, generally employed in cities, places each fixture connected with the supply under the same pressure as the street main, unless a reducing valve is introduced, thus often subjecting the work to needless high pressure and always to the widely varying conditions and quality of service incidental to such use. In the direct system it is good practice, where at all practicable, to pipe and fit the work generally for pressure not exceeding 50 pounds per square inch, and then use a reducing valve to maintain such pressure as is required.

The indirect method is almost always necessarily employed in isolated work; and even where municipal service is available, it is generally better for ordinary domestic purposes. With the indirect system, the connection with the street main is carried directly to a tank placed in the attic, or at some point above the highest fixture, as shown in Fig. 2. The supply to tank is regulated by a ball-cock which automatically shuts off the water when the tank becomes full, and opens and refills it again when water is drawn out. All the plumbing fixtures are supplied directly from the tank, and are there-

fore under a constant minimum pressure depending on the distance the fixtures are situated below the tank. The tank storage is a matter of great convenience during repairs to street mains, aside from its ad-

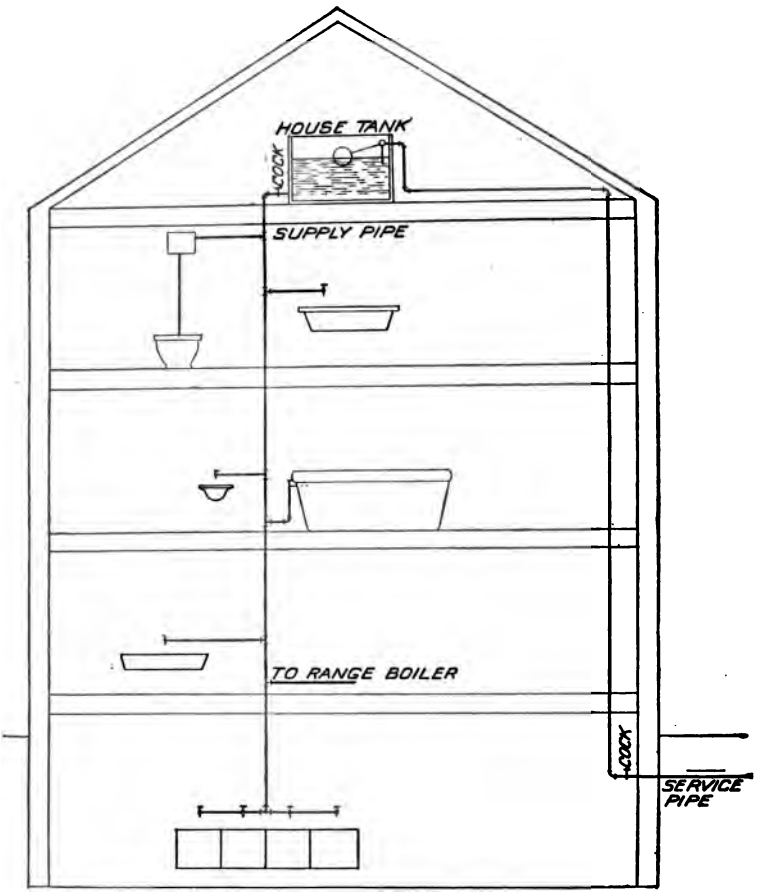


Fig. 2. Indirect or Tank System of House Supply.

vantages of uniform pressure, reduced expense of fitting and maintaining low-pressure work, etc.

In municipalities where the pressure in the main is not sufficient to carry the water up to the house tank in the attic, and in elevated situations, an automatic, electrically-operated rotary or other suitable form of pump is often installed to lift the water. A screw pump like that shown in Fig. 3 is especially adapted to this use when

equipped with an electric motor to start and stop automatically by means of a float in the tank operating an electric switch as shown in the engraving.

Where steam pressure is available, steam-operated pumps are very frequently used, and are invariably arranged for automatic service whether there are engineers regularly in attendance or not. A device that may be attached to steam pumps for this purpose is shown in Fig. 4. When the high-water line in the tank is reached, the float closes a valve in the pump discharge pipe, thus promptly increasing the pressure in it so as to actuate a piston through a pipe connection from the pump discharge to the regulator beneath the piston head. The regulator is shown complete, in detail, partly in section, in Fig. 5. Raising the piston shuts off the steam supply to the pump at the governor valve. When the water line in the tank is lowered, the float falls and the ball valve opens, relieving the pressure in the pump discharge pipe and allowing the steam governor valve to open by the action of the coun-

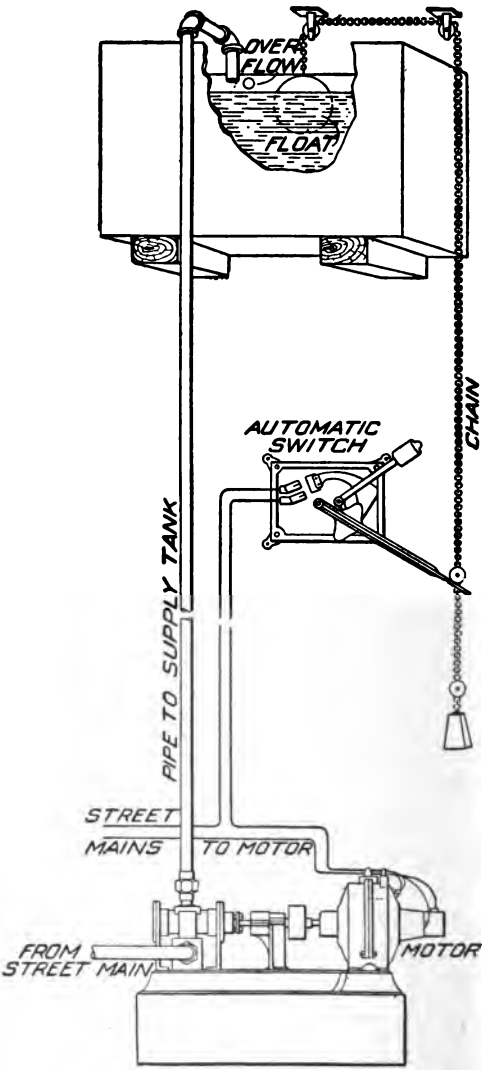
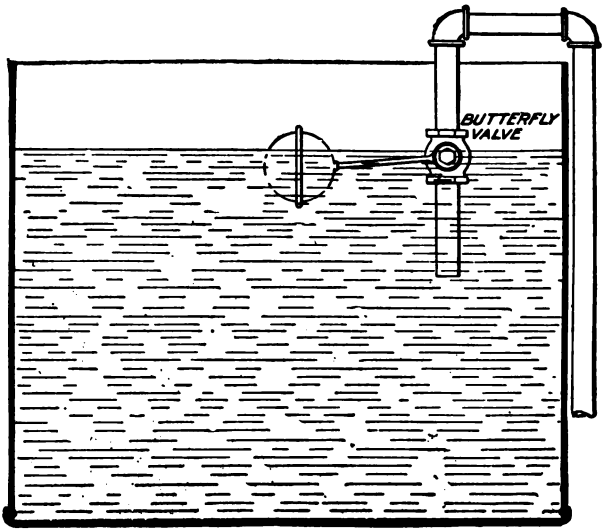


Fig. 3. Electrically-Operated Pump for Lifting Water to Tank. Automatically Started and Stopped by Means of Float Operating Electric Switch.



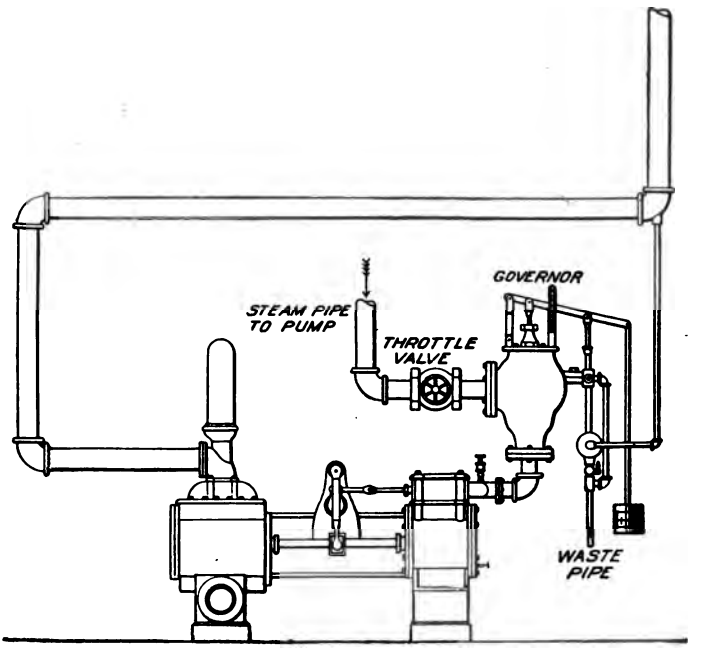


Fig. 4. Steam Pump Equipped with Regulator Operated by Float in Tank, Securing Automatic Service.

terweights attached to the lever arm, as shown; and the pump then works regularly until the lifting of the float by the rising water again closes the valve in the pump discharge and repeats the action described.

Outside of corporations, the supply may be from an elevated

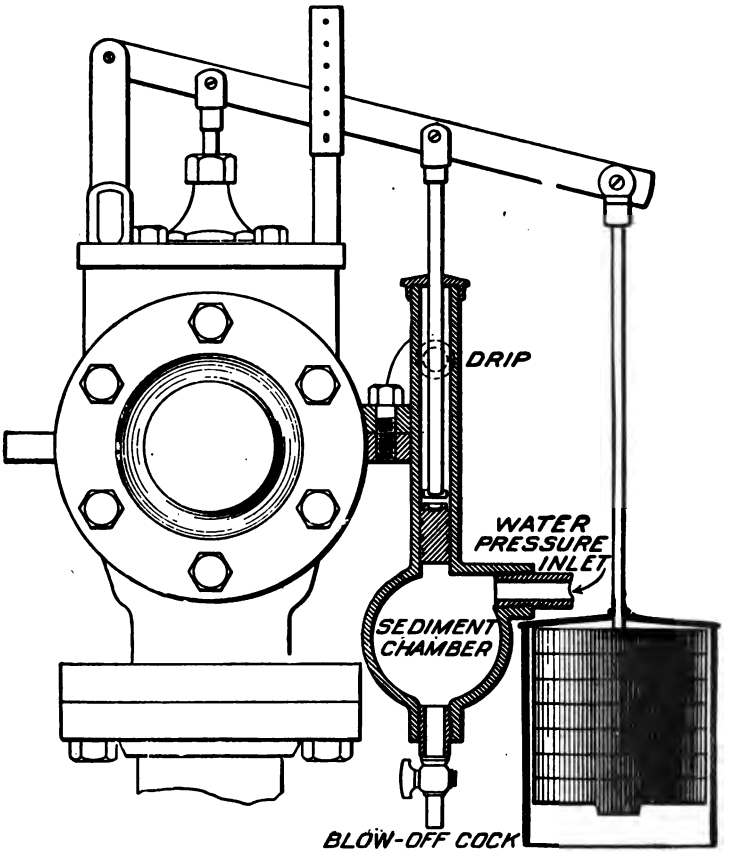


Fig. 5. Steam Pump Regulator (Shown Partly in Section) Automatically Operated by Valve Controlled by Float in Supply Tank.

spring or stream, or from wells, cisterns, or other sources below the level of use. If the natural supply is high enough, it may be conveyed into a tank of sufficient height without intermediate apparatus. The tanks must be placed well above the highest faucet in the building, should be provided with a cover, and must be covered with a non-conducting material to prevent freezing during the winter months.

WATER-SUPPLY SYSTEM ACCESSORIES

WATER MAINS

Lead Pipe. Over two thousand years ago, lead water mains were in use. They were elliptical in shape, the joints being made with a burned seam. Of course, they would not meet present-day requirements, being too expensive and incapable of withstanding the internal and external pressure.

Wood Pipe. The manufacture of bored pipe for water mains has been somewhat revived in recent years and a considerable amount of such pipe is now manufactured under the name of *improved Wyckoff pipe*. The pipe is made from solid logs, but it depends for strength upon spiral bands of flat iron which are wound tightly about it from end to end. The exterior of the pipe is coated with pitch as a protection to the bands. The joints are made by means of wood thimbles fitting tight in mortises in the ends of the pipe and, in laying, the sections are driven together by means of a wood ram. The interior surface is smooth and continuous. The pipe is made in sections 8 feet long and from 2 to 17 inches in diameter. The bands are spaced according to the pressure. Branch connections are made by means of cast-iron specials which have long sockets into which the wood pipe is driven. About 1500 miles of this pipe is reported to be now in use. It is very durable and, where transportation charges are not excessive, is said to cost less than the cast iron.

Wood-stave pipe is another form that has been extensively used in the West. The durability of wood pipe is chiefly a question of the life of the bands. Wood itself, when kept saturated with water, has almost unlimited life. Old water mains have been found in excellent condition after hundreds of years of use.

Vitrified Clay Pipe. In a few places, vitrified clay pipe has been employed for conduits. It is cheap, indestructible, and, when the joints are carefully made, the leakage is very small. It is ordinarily used under no pressure, but in one or two instances has been designed to carry considerable pressure.

Concrete Pipes. Both reinforced and plain concrete pipes are made and give satisfaction if they are not subjected to any great internal pressure. In many localities the concrete ingredients are difficult to procure, which, of course, makes them very expensive.

Cast-Iron Pipe. Cast-iron pipe is used extensively for water mains. The pipes should be coated externally and internally with a solution of tar, pitch, and oil. This solution is placed in a large tank, and when the mains—which may be of any internal diameter, according to the requirements, and about 9 feet in length—are red hot, they are submerged in the solution and allowed to remain until the contents of the tank are all one temperature. There are two methods of joining these pipes, one being to cast on each pipe a flange which must be turned quite true and to connect the pipes with stout bolts and nuts, having a sheet-rubber washer placed between the flanges and drawn up tight by means of the nuts. The other method being to cast on each pipe a spigot and a tight collar, the joint being made with oakum and molten lead. As the lead shrinks on cooling, it is necessary to caulk or stave the lead into the sockets with a caulking or a staving tool. On no occasion should the depth of the lead in the socket be less than 2 inches.

Wrought-Iron and Steel Pipe. Wrought iron and steel have been used to a considerable extent for water pipes and, for large pipe lines, these materials present considerable advantage over cast iron. Since steel is much stronger than cast iron, the use of it gives a much lighter pipe and an advantage as regards transportation but a disadvantage as regards durability, especially for small sizes. Special forms are not so readily constructed of steel and for distributing mains cast iron is preferable. Another disadvantage of steel pipe is that with the ordinary riveted joints, on account of the increased friction, a considerably larger pipe is required than if a smooth cast-iron pipe is used.

Small sizes of pipe may be made by means of the lap-welded joint, the spirally-riveted joint, or the longitudinal lap-riveted joint. Such pipes are made in sections 12 or 15 feet long and are connected in the field in various ways, such as by a screw coupling; by means of a cast-iron bell and a spigot consisting of a steel or wrought-iron band; by riveting; or by merely driving the sections together. For large sizes, riveted, longitudinal, and circular joints are usually employed. Single sheets are bent and riveted to form one section of pipe which may be cylindrical in form or made with a slight taper and the sections put together in stovepipe fashion.

Changes in direction are made usually by forming one or more

joints at a small bevel. Two or three standard bevels of small angle may be adopted and any desired curve made by the use of one or more of these bevels. Branches, etc., for the ordinary sizes of pipes, are usually made of cast iron and are riveted or bolted firmly to the steel pipe. Valves are joined to the pipe in a similar manner by means of cast-iron flanges.

Materials for Service Pipe. The nature or character of the water governs the material used for services, risers, etc. Assuming the water to be soft, copper, iron lined with copper, iron lined with tin, and lead lined with tin—the tin having no amalgamation with the lead—can be used with safety. Iron, lead, zinc, and brass cannot be used with soft water; but if the water is hard any of the aforementioned materials will suffice. Cost and ease of working are the only items which need to be considered in making the selection. Galvanized iron and malleable fittings are used with hard water.

HOUSE TANKS

Location. Where house tanks are to be used, the greatest possible care should be exercised in placing them in proper positions away from all sources of contamination and making sure that the connections are safe and sound. Polluted water has been responsible for thousands of cases of typhoid fever, cholera, plumbisolvent, zinc poisoning, and diarrhoea. A storage tank is placed in an attic and no cover provided for it. The water readily absorbs any foul gases and all manner of filth. Mice, rats, and birds often find their way into the tank and die, rot, and pollute the water. Again, many cases of illness occurred a few years ago owing to the overflow being connected with the soil pipe and water-closet flush pipes coming direct from the storage tank without any other tank intercepting.

See that the tank is placed in a room built especially for the purpose. It must be properly lighted and ventilated and the tank itself provided with a cover. The overflow must end in a water-supplied sink with a deep-seal trap.

Types of Tanks. The following materials are used for house tanks: wood lined with lead, plain iron, galvanized iron, copper, slate, and solid porcelain.

Lead-lined tanks are practically obsolete at this time. They are

not only very expensive, but soft waters readily attack the lead, causing the consumers of such water to suffer from lead poisoning.

Plain iron tanks are satisfactory when used in connection with hard water. They are light, cheap, and durable, but if the water is soft, it will be discolored and the tank will rapidly corrode and leak.

Galvanized-iron tanks are used extensively and are cheap, light, and fairly durable. Connections with them are readily made and, for hard water, it is a very satisfactory tank. However, the zinc is no protective coating against soft water and, in time, the zinc is eaten away in patches; consequently, the water is discolored and dangerous.

Copper tanks are good for all kinds of water, but they must not be soldered. The sheets should be riveted together and, if necessary, supported with a wood casing.

Slate tanks are not affected by any kind of water but are somewhat expensive and heavy. Furthermore, being made in five pieces, the joints are liable to leak and, in consequence, much havoc may be wrought to the building.

Solid porcelain tanks are ideal from a sanitary standpoint but are expensive and heavy and much difficulty is experienced in drilling them for the necessary connections.

PUMPS

Hydraulic Water Lifts. Hydraulic water lifts have of late years been used to elevate water by water pressure. With them various arrangements of piping to suit a wide scope of conditions are possible. If city water pressure does not reach the upper floors, the pressure on the lower floor may be employed to lift the supply for the upper floors, either for direct use from the pipe as usual, by aid of a closed accumulator, or by first delivering the water elevated into an open tank and then piping as in the ordinary tank installation. The power-water of a lift (that used to elevate with) is not wasted as in the case of a ram. The service for the low-level fixtures is simply carried through the power cylinder of the lift, and elevation takes place only during the use of faucets connected to the street pressure. The amount of water elevated by this system is therefore governed by the consumption

on the lower floors; and the ratio of amount elevated to that used directly from the initial pressure, is as the capacity of the power cylinder to that of the one operated by it. An approximate estimation

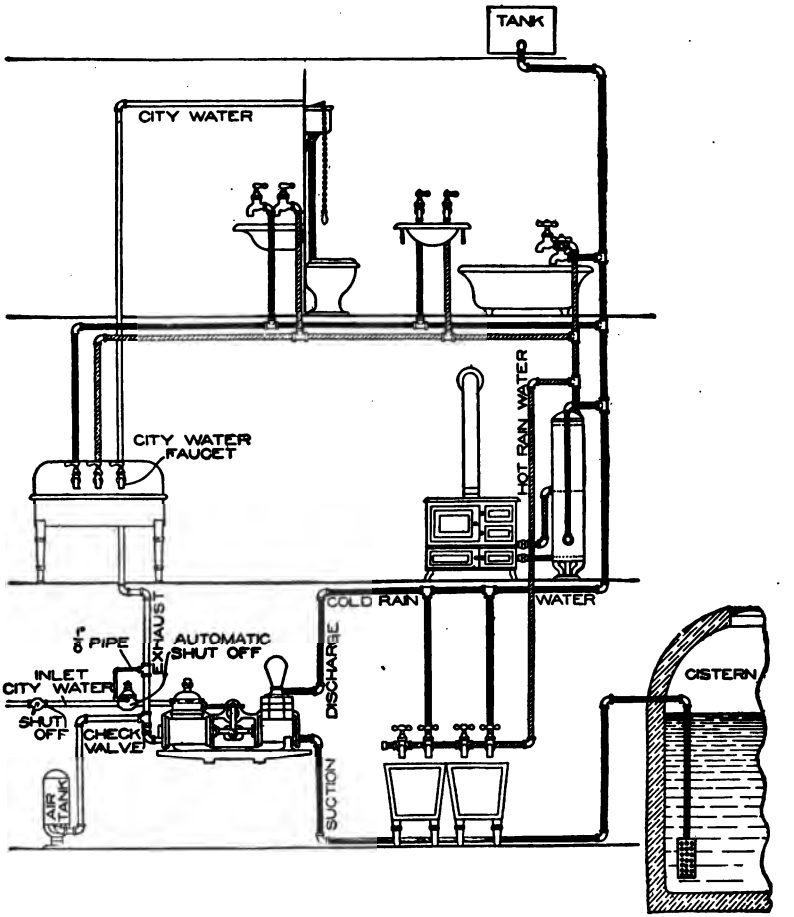


Fig. 6. Method of Using City Pressure to Pump Soft Water for House Supply.

of the relative amounts of elevated and initial supply needed, must, on this account, be made before a proper lift can be selected.

Cistern water can also be lifted by this method to either an open or closed tank, using or wasting the power-water according to circumstances. In Fig. 6 is shown a plan by which hard city water pumps rain water for baths, trays, etc., by means of a water lift.

Pneumatic System. What is termed the pneumatic system is a feature of modern plumbing in many isolated buildings. The manner of pumping, though it may be accomplished by any of the means mentioned, is usually by hand pump. Instead of the open elevated tank supplying the fixtures by gravity, a closed tank capable of withstanding the required pressure is placed either in the cellar or in the ground. The pump is connected with the tank at the bottom, with a check-valve between the pump and tank. The house service is also taken from the bottom of the tank. Pumping the water in, crowds the air in the tank into the upper portion, so that, by the time the tank is three-quarters filled with water, there is in the neighborhood of four atmospheres' (or 45 pounds') pressure on the gauge. At one-fourth full, the gauge pressure would be 7½ pounds; one-half full, 15 pounds; seven-eighths full, 105 pounds. When the tank is placed horizontal, the simple definite relation of altitude of contents in the tank to contents is in evidence only at half-full. Above the center the percentage of contents exceeds that of the altitude, while below, it is less. With vertical tanks however, as shown (level), the altitude is always in proportion to the contents. Part of the storage tank being occupied by air, and much of the water in it not available under the pressure thus established, higher pressures are often employed, either by pumping air into the tank with a separate pump, or by

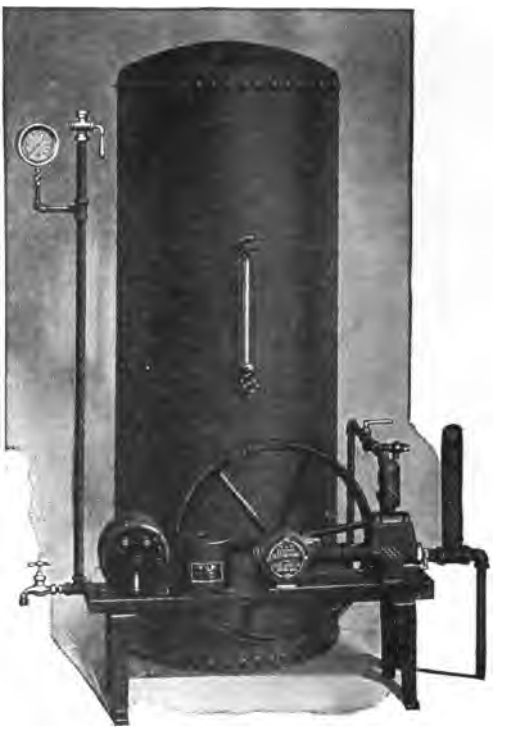


Fig. 7. Hydro-Pneumatic Water System with Electric Pump.
Courtesy of Crane Company, Chicago.

use of a pump delivering both water and air. The former is the more satisfactory.

A type of pneumatic service apparatus is shown in Fig. 7. The good features of these systems are that cheap and permanent support for the tank is secured; the water is kept cool in summer and free of frost in winter; and, if sufficient capacity is provided, fire pressure for a time can be obtained. The disadvantages are that plain iron cylinders injure the water; galvanized cylinders are costly; large cylinders are hard to make and keep air-tight through the strain of

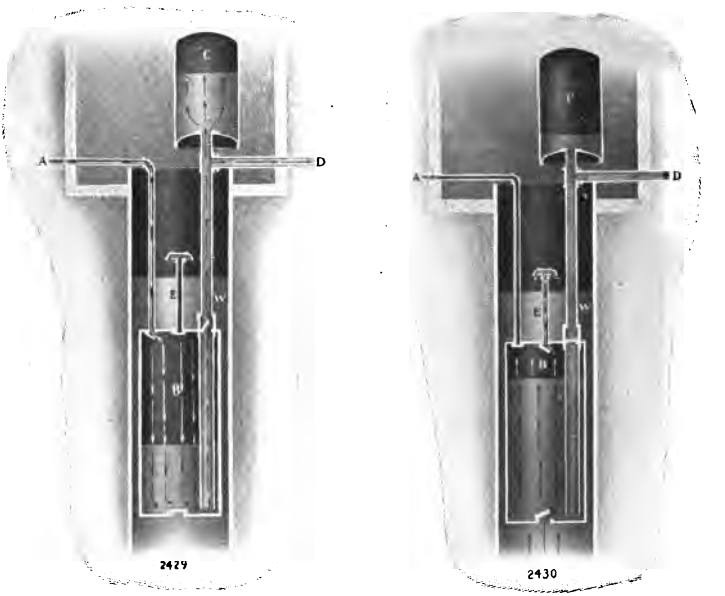


Fig. 8. Pneumatic Service Apparatus, Showing Valves in Position for Discharging (Left) and for Refilling (Right)
Courtesy of United Pump & Power Company, Milwaukee, Wisconsin

transportation and installation; caulking seams is expensive; a battery of small cylinders offers numerous seams and connective joints as chances for leakage, and only a fraction of the water is available under ordinary pressure; high pressure is severe on the pump and parts; and hand pumping is very laborious.

A system superior to the above is that made by the United Pump & Power Company, Milwaukee, Wisconsin, and is shown in Fig. 8. The water-storage tank, which on many occasions has been the means of contamination, is not necessary with this system, the water being

delivered under pressure direct to the faucet. A pump is placed in the well, or other source of supply, and is operated by compressed air which, by means of an automatic valve, forces the water out of the two cylinders, providing a steady continuous flow at high pressure.

Fig. 9. Sectional Elevation of Dwelling, Showing Installation of Pneumatic Service System
Courtesy of United Pump Power Company, Milwaukee, Wisconsin

The illustration at the left, Fig 8, shows the cylinder *B* discharging, that at the right with the valves in position for refilling. The pump operates only when water is drawn at the faucet and starts and stops automatically when the faucet is opened and closed.

The equipment, shown in section, Fig. 9, is very simple and consists of motive power capable of producing one horsepower or

more, also a small air compressor, a storage tank for air, and a pneumatic pump. This equipment may be located at any convenient place; the pump is submerged in the well, and having made connection and started the compressor, the air is stored in the tank at any desired pressure.

This compressed air is now stored power which operates the pump and is used only when water is drawn from the faucet. The compression need not be started again until the tank requires recharging. A pressure reducer on the air lines maintains an even pressure of water at the faucet, regardless of the amount of air pressure in the tank.

WASHER AND HYDRANT

Assuming that a house is to be piped from city pressure, the fixtures of the yard are nearly always a street washer and a yard hydrant. The principle of these is the same; but the washer is primarily intended for the attachment of hose for sprinkling purposes, while the hydrant body extends above ground so that vessels may be placed under the nozzle to have water drawn into them. The hydrant may be used to draw either with or without a hose thread on the nozzle, while no use of the street washer is possible without the thread; hence, there may be a material difference in the water rates, according to the possible uses the water can be put to.

The valve of these fixtures is placed at the bottom, 2 to 5 feet below the surface, according to the climate. The working parts can be withdrawn for repairs without disturbing the body. Waste-holes are open when the pressure valve is closed so that the stem and body will empty to below the freezing point. The pressure waste-hole is not entirely closed until the hydrant or washer is approximately wide open. For this reason, turning the water only partly on when drawing or sprinkling, while it does no apparent harm, is likely to lead to trouble. If the ground is clay, it does not soak up the waste. If there is a cellar near, it will sooner or later find its way into it. There is much to be learned in judging what ails leaking hydrants. Dripping at the nozzle may indicate a short stem, a chip under the washer, a washer too thin, or a bent stem. Water flowing steadily but slowly from the ground may be caused by a leaking pipe, a loose collar, or a loose, twisted, or damaged pressure washer.

Even if care is taken in this regard and the hydrant valve fully opened when in use, there is a liability to serious dampness from the wastage into the ground of the water stored in the standpipe above the valve, which is always after a short period discharged below the ground-level through the waste-hole.

The least trouble one may expect from careless use is that the ground around the fixture will be saturated, and the body stand full of water instead of draining away; and when cold weather sets in, damage by freezing will result. The action of frozen ground in pulling up on the body of these fixtures is severe. To avoid trouble from waste water and frost, certain precautions are taken in good work. The end of an iron pipe is too rigid for direct connection. To overcome this, fittings and nipples are added so as to make the connection indirect and secure the required spring in the joints and pipe, as well as freedom from torsion. A short piece of lead pipe answers the same purpose. A cavity formed about the base of the fixture and connections, permits freedom of action and greater immunity from frost breakage.

Usually, the only positive way to insure the waste water draining away harmlessly, is to bore a dry-well under the fixture and fill it with broken rock or fragments of hard brick. This filling should extend a little above the bottom of the fixture, and should have a stout cloth folded about the body and tucked down around the brick at the edges so that the earth cannot wash in and choke the crevices of the filling.

SERVICE PIPES

The supply to the house should have a stop and waste immediately outside the wall—or, preferably, just within the wall if the cellar is frost-proof. For outside use, the iron case box is best. Combination stop and waste cocks or valves of similar principle are generally used for this and all other shut-off purposes in plumbing work, where the waste feature is permissible at all. Two separate valves or cocks serve the purpose perfectly, of course; but the waste is likely to be forgotten, thus leaving the pipe filled and subject to frost. Merely closing the stop and opening the waste on a closed line will not, however, drain the pipe. It is necessary, also, to open the faucets in the house, in order that air may enter at the upper end of each line and counterbalance

the atmospheric pressure at the waste so that the water will run out by gravity. If the pipe is sagged at any point, the water retained will have to be blown out with the lungs. If the pipe is trapped by reason of its course, the trap is, or should be, provided with a drain cock, and this must also be opened to insure thorough draining. Air-chambers usually drain without attention as they are only partially filled by compression of the air trapped in them, and when the pressure is off, the air expands again and drives the water out.

While speaking of draining pipes, it may be well to mention the draining and protection of waste traps from frost as well. Closet tanks can be drained by simply pulling the chain when the water is off. The bowl may be emptied with a sponge or rag; but, as communication would thus be opened between the house and soil pipe, this plan is not advised for any kind of trap. Common salt added to the water in the trap will prevent freezing until the contents chill below zero, Fahrenheit. Caustic soda lowers the freezing point, and may be used in earthenware with impunity; but while it has shown no noticeable effect on metals, it should be used with caution, if at all, in both metal and porcelain-enameled iron fixtures. Glycerine and wood alcohol added in equal parts to make a 30 per cent solution in the trap or fixture, will prevent freezing above zero. If the house is being drained for a considerable period of disuse, the best anti-freezing and seal-protecting filling for ordinary traps is, perhaps, glycerine alone. It has the advantage of doing no injury whatever to any material used in such goods, and it will not evaporate.

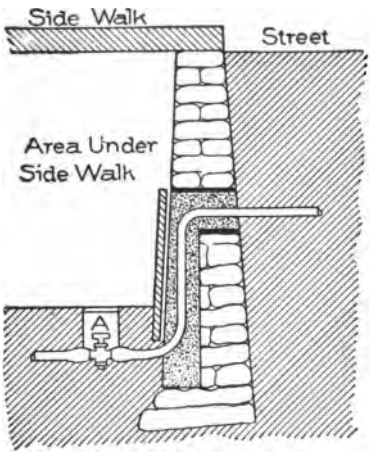


Fig. 10. One Method of Protecting Service Pipes from Frost. Pipe Carried through Wide Channel in Wall and Packed in Mineral Wool.

While it is sometimes necessary to place pipe in exposed positions, plumbing is not satisfactory if so exposed as to freeze during regular occupancy of the house; and every precaution should be taken to locate the fixtures and design the pipe system so that freezing will be unlikely. When exposure cannot be avoided, placing the hot service below the

cold on horizontal runs; providing circulation in the hot service so placed; provision for circulation in, or otherwise warming, the cold service; and employment of liberal air-chambers, may singly or otherwise reduce the trouble from freezing to a minimum. Fig. 10

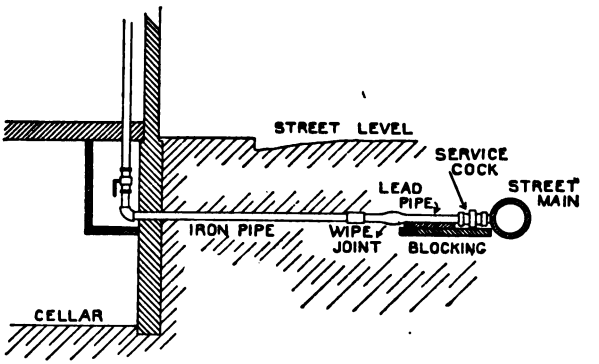


Fig. 11. Iron Service Pipe Connected to Street Main by Lead Pipe to Secure Flexibility and Avoid Effects of Settling.

illustrates the precaution taken in one instance to protect the service in a cold-climate job. Water for the whole job always depends upon the service being in working order, and in this case the character of the ground prohibited drilling down to carry it under the area wall. The wall is shown liberally channeled, thus making three walls and the ends of the box of stone. The pipe is packed in mineral wool. The main stop and waste cock is shown at *A*.

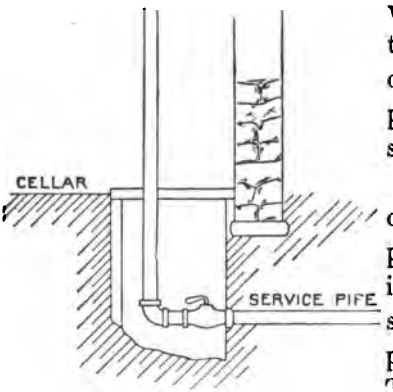


Fig. 12. Service Pipe Carried beneath Foundation Wall.

Fig. 11 shows a method of securing flexibility necessary to compensate for settling when connecting an iron service pipe with the street main, a section of lead supply being wiped in next the main. The service box and stop-cock at the curb are not shown in the engraving. The earth under the pipe should be rammed down solid after the connections are made, so that pressure from above will not break the connection or strain the cock. The connections between the lead and iron pipes should be made by means of brass ferrules

and wiped joints. A stop and waste cock should be placed in the service pipe just inside the cellar wall, and in a position where it will be accessible in case of accident. A drip pipe should be connected with the cock tube, for draining away the waste water, which would otherwise saturate the frost-proofing and chill the pipe by conduction.

Simple boxes with multiple walls with air-space between, may be employed in protecting pipes against frost; or a single box with mineral wool, hair, felt, shavings, or granulated cork may suffice. When the service is brought under the foundation before entering the cellar as shown in Fig. 12, frost-proofing is seldom necessary.

DIRECT WATER SUPPLY

The salient features of the supply system for city pressure, not already mentioned, are; separate shut-off cocks for the supplies of each fixture; separate lines to each isolated fixture or to each group of fixtures; $\frac{3}{4}$-inch supply to all sinks, trays, and baths; $\frac{1}{2}$-inch supply to water-closet tanks; and $\frac{1}{2}$ or $\frac{3}{8}$-inch branches for lavatories; no traps in supply lines; return circulation from lavatory hot supply so that hot water can be drawn instantly at the lavatory faucet; storage cylinder for hot water amply large to furnish a hot bath without robbing the hot service for other purposes; faucet on sediment pipe, so that water can be drawn at that point when desired; and proper stove connection. All shut-offs in direct-pressure work, except where located immediately at the fixture, should be *stop and waste*, with the waste on the house or fixture side.

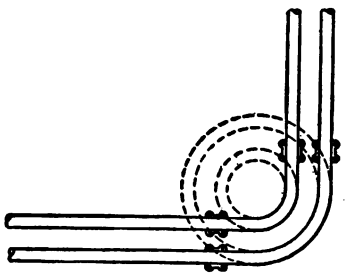


Fig. 13. Method of Laying Out Concentric Bends in Parallel Pipes.

On single runs of lead pipe, make all bends on the same size of pipe, of the same radius. Make no bend on any size pipe, except tubing, of less than 3-inch radius to the center of the pipe. Give $\frac{5}{8}$ and $\frac{3}{4}$-inch pipe bends 3-inch radius; and $\frac{7}{8}$ and 1-inch pipe bends, 4-inch radius. Where two pipes of different size run together and bend in opposite directions, give the bend of the smallest pipe the radius prescribed for the bend in the larger one, if practicable.

TABLE III

Data Relating to Offsets in Iron Pipe Work

Bend	Equal to	Multiply by
$\frac{1}{8}$	60 °	1.15
$\frac{1}{8}$	45 °	1.414
$\frac{1}{12}$	30 °	2.00
$\frac{1}{16}$	22½°	2.61
$\frac{1}{32}$	11¼°	5.12
$\frac{1}{64}$	5⅝°	10.22

Where more than one pipe bend in the same direction, make the bends of the pipes form arcs of concentric circles as shown in Figs. 13 and 14. To set off the offsets in Fig. 14, draw line *A*, at the end of the first bends; and with the proper radii, describe the arcs that outline them. Set off one-eighth of the circumference of the circle corresponding to the larger arc, and draw line *C*, cutting the center of the circle. Then produce dotted line *D*, and set off a square the diagonal of which will give the straight pieces of the offset desired; and produce *E* parallel to *C*. Next describe the arcs outlining the second bends, finding the center on *E* from radius equal to the corresponding radius at *A*, which will be the intersection for *E* and *B*. This brings the offset parts the same distance apart as the runs are. To accomplish this result with iron pipe, the centers of 45-degree fittings would have to be placed at the intersections of tangents of the arcs extended, thus throwing the fittings in a line deviating 22½ degrees from one perpendicular to the run. This plan is the strictly correct way for iron pipe, as well as lead pipe work; but on account of the

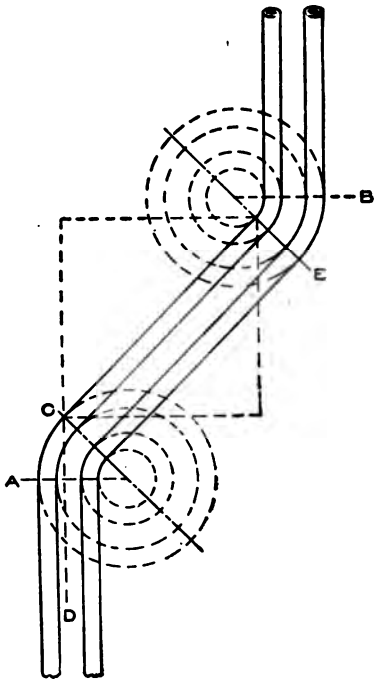


Fig. 14. Method of Laying Out Offset in Parallel Pipes to Preserve Equal Distance between Them

difficulty of laying out the work, it is more usual to line up offset fittings perpendicular to the runs, and let the offset pieces fall, as they will, nearer to each other, center to center, than are the lines of the runs.

Offset pieces from center to center of fittings exceed in length the distance offset in the ratio indicated by the constants given in Table III. To find the length of an offset piece, center to center of fittings, simply multiply the distance the line is to be offset, by the constant given for the particular fittings to be used.

Water Supply to Fixtures. In a small installation, the running of a separate supply to each fixture is desirable. There is, however, a limit to the number of fixtures and isolated location of them, beyond which the furnishing of separate supplies to each faucet is folly, as, in addition to the confusion of pipes, and the expense, it leaves more material open to possible failure, and does not reduce the chances of lack of service in porportion. The sole object of separate supplies (and of cocks, too) is to avoid losing the service of other fixtures during times when one of them, or its supply or waste, must be repaired.

In a residence job, two main supplies to each bathroom, with separate stops for each fixture, are sufficient; and a return circulating pipe from the lavatory will serve every purpose, as the water is kept hot in the main line to the bath branches.

The pump and kitchen-sink work of a country job of this type is shown in Fig. 15. The pump air-chamber discharge leads up to and over tank. An opening near the pump provides for elevating water by other means if desired. The pump faucet is piped up and over so as to discharge into sink. The tell-tale pipe from tank leads down behind sink-back and out through a nozzle, as shown. The sink supplies are fitted with stop-cocks. The pressure being light, there are no air-chambers to the sink faucets. The supply to pump is from a large cistern.

Fig. 16 shows the supplies of the same job, on the kitchen ceiling. The system provides positive circulation to keep hot water near the bathroom fixtures. The hot supply is on the left side for each fixture. There is only one pipe crossed, and it does not interfere with draining the job. There are no traps in the supplies, nor drain cocks, to be forgotten. There is a relief line from the reservoir to the tank, so that it is not possible to close every means of escape for vapor or steam

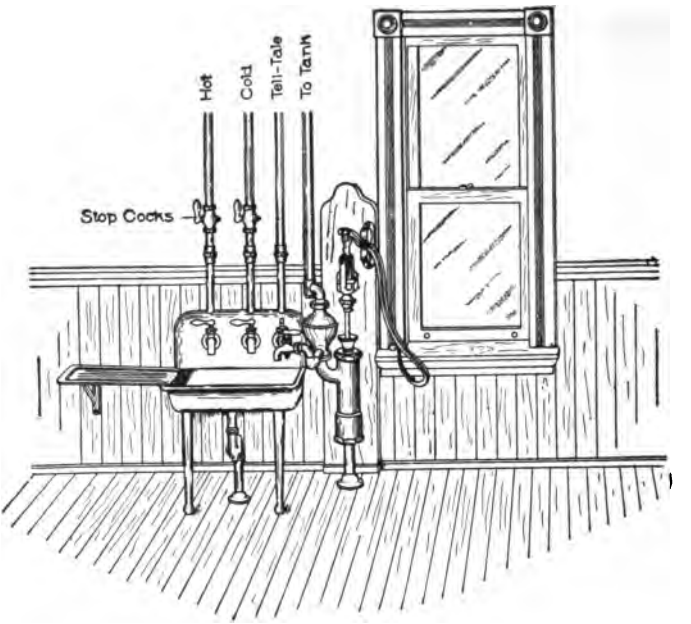


Fig. 15. Pump and Kitchen-Sink of a Country Installation.

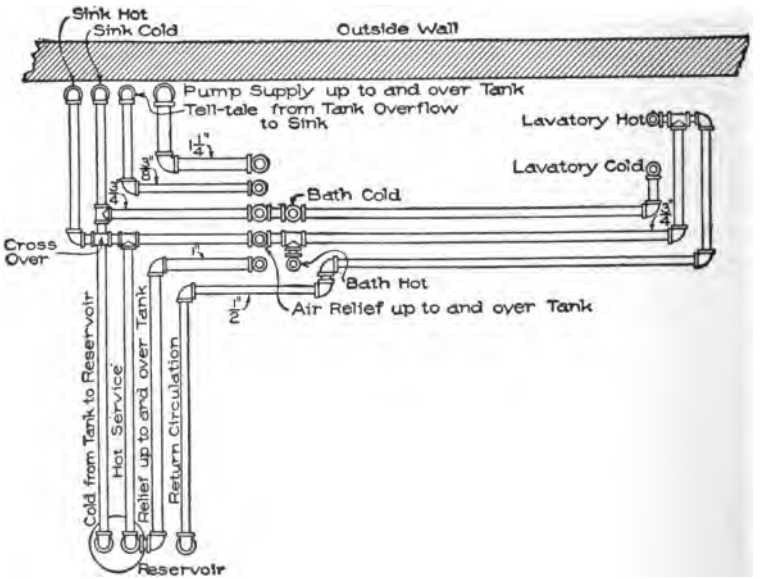


Fig. 16. Plan Showing Layout, on Kitchen Ceiling, of Supply Pipes in Installation Shown in Fig. 15.

from the reservoir. The hot supply and cold service are both open to the air at the tank.

The disadvantage of this job is that the cocks which stop the hot water to the bathroom are over the reservoir. While each fixture is controlled separately, by cocks in addition to its regular faucets, all the lines are not under control individually. This arrangement embraces every feature essential to good service and with the least possible material. The nickeled supply in bathroom is thus reduced to a minimum, and the chances for leakage to do damage are greatly lessened. For comparison, the kitchen work of an actual installation with separate supplies, having one bathroom and three odd fixtures, is shown in Fig. 17. This number of fixtures is considered about the limit in strictly separate supply work for residences, when all the lines radiate from one point, as they do in this case. In order that their purpose may be understood, the pipes shown in Fig. 17 are numbered. Pipe 1 carries the water from the house force-pump to the tank, and is arranged to discharge over the top of the tank. The tell-tale pipe, 2, is from the tank, and discharges in the sink, so that the person using the pump will know, when water flows from it, that the tank is full to the overflow level. The cold-water supply to the butler's sink is No. 3. No. 4 is the hot-water supply to the same fixture. Pipe 5 is the return circulation from the bathroom hot supply. To make proper circulation certain at all times, regardless of the trap in the hot-service pipe made by dropping from the boiler and running across under the sink before rising to the second floor, the hot-service pipe is continued to the attic and a return made from there, an air-pipe being taken from the highest point over the tank, to prevent its becoming air-bound. The position of the stop-cocks is such that they will drain without giving special attention to the waste water, which discharges into the sink; and the cocks are within easy reach from the floor. Pipe 6 is the cold-water supply to the bathroom fixtures. The supply to the water-closet tank is taken from pipe 9, which passes under the closet room, a cock being placed just above the floor. Pipe 7 is the hot-water supply to the bathroom fixtures. The main cold supply from the tank is pipe 8, which has a cock over the sink, and is also provided with a valve at the tank. Pipe 9 supplies cold water to the laundry, the hall lavatory, and the water-closet already

mentioned. Pipe 10 supplies hot water to the laundry and the hall lavatory.

All of the service pipes, both hot and cold, above the first floor, are continued upward from the kitchen ceiling through a partition to and over the tank. This allows air to enter the pipes and drain the lines when the stop-cocks on them are turned off.

Baths do not need circulation for the same reason that lavatories do. Lavatory faucets are small in nozzle, as a rule; only small quantities of water are needed at a time; and it is annoying to have to waste time in drawing out cold, "dead" water and enough more

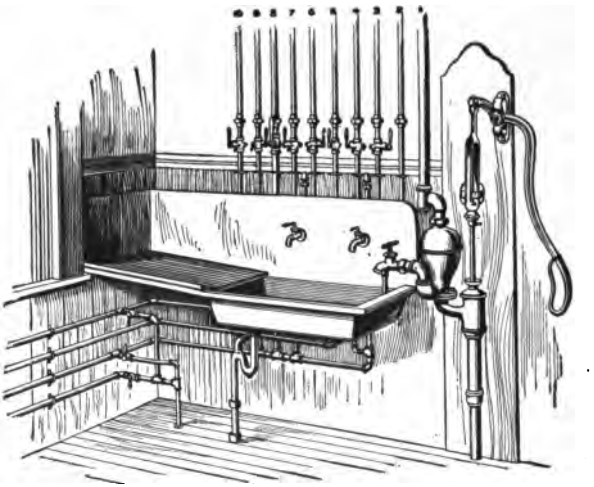


Fig. 17. Kitchen Arrangement of a Separate Supply Tank Installation.

to warm the pipe line, before warm water can be had at the faucet. Where the water must be pumped by hand such needless waste is still more aggravating. Kitchen sinks are close to the hot supply source, and do not need circulation. Lavatories and other fixtures remote from the bath or main toilet room, are sometimes served from the circulating loop instead of separately.

Water Hammer. Water hammer is a knocking noise heard in water pipes and, no matter where it commences, it will travel the entire length of the pipe. It occurs more in horizontal than in vertical pipes. In the case of a plug, spring, or other quickly closing faucet, the water is driven back a few inches in the pipes, leaving a vacuum. The momentum of the water then causes it to flow back

through the vacuum and brings it into contact with the faucet. In bad cases, the pipe may burst with the continuous shock it receives. To obviate this, slow-shutting faucets should be used or an air pipe or vessel should be fixed as near as possible to the trouble.

Now that iron has superseded lead in nearly all work, there is little opportunity of showing proficiency in joint wiping, except on water services and an occasional riser, so the methods of joint wiping will be explained here.

METHOD OF WIPING JOINTS

Watching somebody wipe joints, a clear description of how it is done, a thorough knowledge of the theoretical process, and acquaintance with the traits and qualities of the materials used, are essential; but practice in the art of wiping joints has more to do with making one proficient than has mere practice to do with proficiency in any other line of work. A Hottentot would succeed about as well in engrossing a set of resolutions, upon his first introduction to English and a pen and ink, as the most skilful person in other lines would in the work of wiping a joint at the first attempt. One may give the closest attention to the manual operations of making a thousand joints when the cloth and ladle are in the hands of someone else, and yet fail to remember the how and wherefore of a hundred movements absolutely necessary to success. Some general remarks are therefore all that will be of real benefit to any one previous to practice.

The same general result must be attained under a great variety of conditions, regardless of position or size or character of the pipe. The temperature and composition of the solder; the temperature of the weather; the kind, size, and position of the joint, etc., must be reckoned with in every instance, and each modifies the proceeding more or less at some stage.

Before commencing to wipe a joint, one should be positive that it is firmly set; that the cleaning is well done and of proper length; that the junction of the ends is well made, so that solder will not run through into the pipe; that the surrounding edges are well soiled, pasted, or otherwise protected, so that the solder will not adhere except at the cleaning; that the pipe is dry inside and outside; that no undue current of air is passing through it; that there is enough solder in the

pot to get up the heat and do the work; that the solder is hot enough; and that the cloth is in good condition.

To prepare for a joint, square the end of the pipe; see that the bore is true; rasp the spigot end evenly down to the bore, a little more obtuse to the outside surface than it is intended to make the boring or opening of the receiving end to that of the interior surface. Always rasp against the end of the pipe, so that no burr is made on the inside and so that none of the raspings get into the pipe. If the receiving end is to be opened with a turn-pin, the rasping on the spigot end should be made according to the taper of the turn pin, and the bell end should be rasped down only partially, leaving stock enough to stretch when the end is expanded with the turn-pin. If the receiving end is to be opened with a tap-borer, then the spigot end must be rasped down in accordance with the angle of its boring. A coarse rasp will do to rough the work with; but one of fine teeth should be used to do the finishing so that the shave-hook will remove its marks. When the ends are thus prepared, soil them back three or four inches; and when dry, clean with a shave-hook, cutting rather deep at the beginning of the cleaning so that there will be a slight thickness of solder at the edges of the joint; otherwise it would be impossible to wipe the edges clean and perfect, because the feather edge will chill too quickly. Before setting the joint, the tip edge of the spigot end and the bottom of the receiving end should be soiled, so that the two soiled parts will come together when the pipe is in place. This keeps solder from sweating through into the pipe.

The length of cleanings does not increase with the diameter of the pipe. The idea is to have the solder contact surface in proportion to the strength or purpose of the pipe. A round joint on $\frac{5}{8}$-inch pipe and one on 8-inch soil pipe should be about the same length—2 to $2\frac{1}{4}$ inches. On 4-inch soil pipe, the average width of a joint is about $1\frac{1}{2}$ inches. When the pipes to be joined are of different metals, it is best to increase the length of the joint somewhat, or extend the tinning. For instance, on copper pipe—especially for distillery use—some kind of galvanic or corrosive action takes place which destroys the union between the solder and the metal of the pipe. It is therefore usual, on distillery work, to tin across the end of the pipe and back on the interior, in addition to the regular joint surface outside, making

the tinning continuous, as its length and continuity seem to determine the period of time the joint will last.

Difference in the ratios of expansion, causing a shearing action, appears to have much to do with the life of joints when lead and brass, lead and copper, or lead and iron are joined together by wiping. This is noticed more on water-back connections than elsewhere in the regular line of plumbing. When lead is joined to lead, the difference in the coefficients of expansion for the mass of solder and the metal of the pipe with which it is in contact, is so slight that little trouble is experienced in this way. The contour of the joint may be decided by allowing the thickness of solder at the middle to equal one and a-half times the thickness of the wall of the pipe. This holds good for supply pipe where the solder used is 40 to 45 per cent good tin and 55 to 60 per cent pure lead. On thin wall soil and waste pipe, or where coarser solder is used, twice the thickness of the wall is better The solder forming the joint must be patted up compactly before wiping.

The beginner should keep the solder hot, leaving the pot in the furnace while practicing, so that he can put back and re-melt the cold batches from time to time, and continue to pour and re-wipe without loss of time. He can do no better than to try to imitate the motions of those who know how, whether he yet fully comprehends the reasons or not. Practice will soon teach him a few points which words cannot explain to the inexperienced. Lead and tin, not being of the same specific gravity, stratify more or less when melted, the tin rising to the top. For this reason, the molten mass should be skimmed and well stirred before dipping out any to wipe with. Never stir solder until ready to use it. Let the novice take the cloth in the left hand, holding it forward so as to cover the tips of the fingers, and take a ladle of solder in the right. Hold the cloth under the cleaning and pour the solder uniformly upon the cleaning at different points, gauging the number, rapidity, and size of drops according to the heat of the solder. A single drop of solder too hot, may melt a hole through a thin wall pipe after it is pretty well warmed up. Keep the ladle moving so that the drops will fall in different places. When some solder gathers on the cloth, put it up on top again, and pour solder on it. When more runs down on the cloth, hold it against the bottom of the pipe to warm the bottom; and continue to pour

solder from the ladle, more particularly now about the edges and even extending the pouring two inches or so out on the soiled part of the pipe on each edge, which will help to warm the pipe and provide heat in the pipe adjoining the edges of the joint to help keep the joint hot enough to wipe the edges clean before they chill.

Do little rubbing or passing on the edges. Let the solder stack up; dig some out of the top of the mass with the ladle to temper fresh solder from the pot, so that pouring a liberal stream of hot solder will do no damage. When the pipe has absorbed enough heat to allow the cold masses at the edges to be lifted easily, pass the mass around a little so as to tin the cleaning. Keep plenty of solder on the cleaning, and let the edges take care of themselves until the last.

When there is a good mass of solder on the cleaning, and the edges are thick and mushy, do extra pouring on the edges to get them thoroughly hot, and then place the solder on the cloth upon the pipe. If it is hot enough, the solder will tend to run off at either side again; but it must be caught and pushed up. Then, with the aid of the thumb or an extra cloth in the right hand, push the solder around keeping plenty at the bottom, and get it patted up compactly into an egg shape with thick edges extending over on the soiled part, as quickly as possible. It may be necessary to pass or rotate the mass so as to get the cooler solder on the top to prevent it from dripping from the bottom. Experience will teach one how to mix the overheated portion with the balance so as to have the solder approximately at uniform temperature at all points by the time the joint is patted up.

The joint roughly shaped as described would hold water quite as well as after it is finished; but the appearance is bad.

Clean the edges first by pulling the cloth around, bearing down on one edge at a time. Then spread the middle and index fingers so as to let the cloth sag between them, and finish the joint by pulling the cloth around while bearing on both edges at the same time, keeping hold of the cloth by pinching it to the palm of the hand with the thumb. Beginners usually draw the cloth lengthwise of the joint to cut off the surplus carried around on the cloth by the finishing wipe; but an experienced person can finish the wiping while the solder is yet hot enough to sweat-in the cloth marks of the final wipe.

If the joint is wiped hot enough, and the heat evenly distributed, the tin spots on the surface when the joint is cold will be evenly dis-

tributed over the surface. If the pipe is hot enough, and the mass of solder too cold at any point, the friction of the cloth will cause the whole mass to rotate on the pipe. If too hot on the bottom, it will bleed the mass by dripping at the bottom. If too cold on top or at any other point, a very poor shape will result—if, indeed, one is able to wipe the joint at all. If the solder is fine, and a single wipe is made after the solder has fallen below the proper temperature, the surface will be covered with briar-like projections. If the solder contains any zinc, it will be brittle and work like cornmeal dough, and drip at the bottom when finished, if finished at all. All brass goods contain more or less zinc in alloy with copper, and it is best never to tin brass in wiping solder, as the zinc will melt out and ruin the solder.

Fig. 18. Butt Sweat Joint

Fig. 19. Blow Joint

Fig. 20. Copper Bit Joint

Fig. 21. Round Wiped Joint on Small Pipe

Many plumbers use two cloths when wiping. To become expert with the cloth, it is better to wipe all kinds of joints with one cloth only, until thoroughly proficient; then, if a second cloth is found to be of real service in some instances, use it.

A beginner may take every advantage to aid him—such as choking a pipe to keep cold air from passing through, heating brass or copper edges with a torch before wiping, placing a live charcoal on a piece of screen wire within the pipe to aid in heating up, wiping large joints in sections and meeting the edges by chalking the finished part as described in connection with tank seams, etc.—but he should never be guilty of making extra joints in order to shirk a difficult position. The quickest plan to master this branch of work, is to make joints in whatever position they happen to be required, instead of trying to arrange an easy way.

Wiped joints should be made wherever practicable; but there are several other styles of joints equally serviceable for certain locations. Fig. 18 is a *butt sweat-joint* made by squaring the ends, tinning one

Fig. 22. Round Joint on Large Pipe

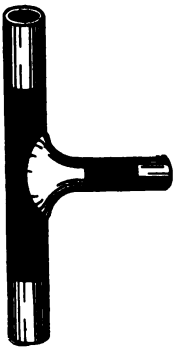


Fig. 23. Branch Joint with Concave Neck

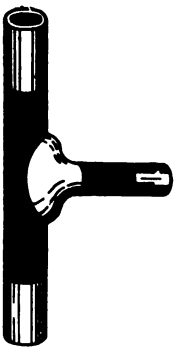


Fig. 24. Branch Joint with Swell Neck

end, and sweating the other to it by heating with a torch. It is the weakest joint made but will, at the outset, stand any strain or internal pressure that the pipe itself will stand.

Fig. 19 is a *blow joint.* The only difference between it and the *copper-bit joint,* Fig. 20, is that the solder is floated by aid of the torch and it is not so heavy as the type shown in Fig. 20. The copper-bit joint is made with the soldering iron, the solder being melted and floated a little at a time until the joint is completed.

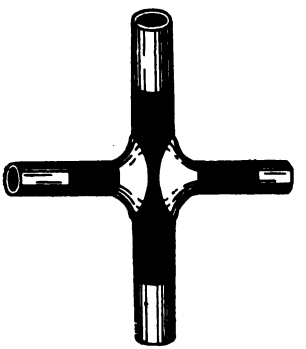


Fig. 25. Double-Branch Cross

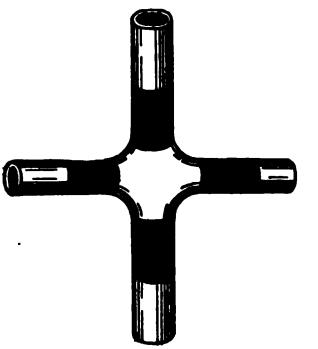


Fig. 26. Regular Cross-Joint

Fig. 21 is a *round wiped joint* on $\frac{5}{8}$-inch supply pipe. For comparison a round joint on 5-inch soil-pipe is shown in Fig. 22.

Fig. 23 is a supply-pipe *branch joint with concave neck.*

Fig. 24 is a supply-pipe *branch with swell neck*, much more difficult to wipe than the style shown in Fig. 23.

Fig. 25 is a *double-branch cross*. This style of cross looks well

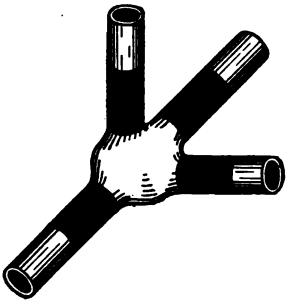


Fig. 27. Angle Cross

Fig. 28. Combination Branch and Round Joint

and is very easy to wipe because one branch may be wiped at a time by protecting the first with chalk or paste.

Fig. 26 is a *regular cross-joint*, more difficult than the double branch because there are four edges to take care of at one heat.

Fig. 27 is an *angle cross*, more difficult if anything than the wiping of the type shown in Fig. 26.

Fig. 28 is a *combination branch and round joint*, sometimes

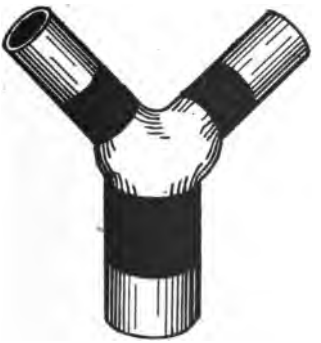


Fig. 29. Y-Joint, Used Generally on Telephone Branch Cables

Fig. 30. Y-Joint on Lead Waste-Pipe

Fig. 31. Common Flange Joint

made where it is most convenient to have a branch joint come at a point where two ends of the supply line must also be joined.

Fig. 29 is a *Y-joint*. This form of Y is rarely wiped except for branch cables on telephone work. Many so-called Y-joints are made

at a Y-angle on lead waste-pipe work, as shown in Fig. 30. As a general rule, none of these combination joints are made frequently enough of late years to keep a plumber in good practice. A common wiped *flange joint* is shown in Fig. 31.

An inclined joint can be set easily with two pairs of old dividers and two blocks to hold the pipe away from the wall. The table to catch what falls, should be a little toward the low side rather than centered under the cleaning. To wipe a joint in this position, pour well out on the soil, and let it stand without attempting to do much with the cloth. Temper the solder from the pot by digging out of the stack on the joint, and pour liberally. After the cold edges get melting hot next the cleaning, lift them into the pot. Then begin to pass the solder around with the cloth. Keep a good mass on the pipe. Pat up when hot enough, and cut the high edge clean first; then the top of the low edge. Then make some trial wipes, without pulling off any solder, to see if the joint is filled out to the proper contour all around. If not, use the surplus to fill the low places; then wipe down to the desired shape quickly. If the joint takes on any symptoms looking as if it had been stung by a bee on the low end at the bottom, cool it quickly with water.

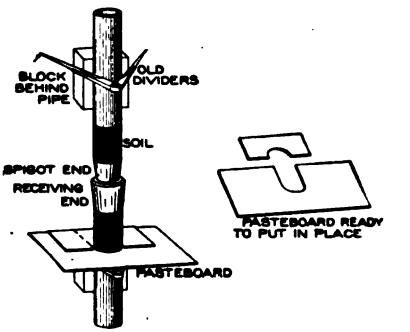


Fig. 32. Upright Cleaning Ready to Wipe.

To protect the wall on a flange joint over new wood wainscoting, such as is often made on sink wastes and vents, a large piece of pasteboard should be fitted over the pipe before the end is flanged. A blind flange joint requires a lead flange to be tacked to the wall over the pipe to support the joint. It is best to fit a lead flange the size of the joint in all cases, as less stretching of the pipe end is then necessary where the flange is also a union of two pieces of pipe. After the joint is finished, the pasteboard can be carefully cut around it and removed, leaving the wall clean. If the flange is to be made over marble, the pasteboard keeps the heat from running away from the edges, and there is less danger of cracking the marble by heat.

An *upright cleaning* is shown ready to wipe in Fig. 32. Plain upright joints are so easy, and occur so frequently, that the art of wiping them is soon mastered. The receiving end should be below and should be opened with the turn-pin and rasped off to suit. Its lower, inner edge and the tip of the spigot should be soiled. The ends should fit well, and the open part taper a little more than the spigot. The bulge helps to keep the solder up; and the cup, if well cleaned, will make a good joint alone. When wiping, either spit the solder on with a stick or pour on the cloth and drift it against the cleaning. Keep the mass up. Endeavor to pour solder on solder instead of on the cleaning. Leave the bottom edge alone until the cold fringe loosens of its own accord. When hot, form up roughly, high, and cut the top edge off clean first; then drag up the settling bottom edge, and fill out the low places; then wipe to finish, bearing the hardest on the upper edge of the cloth. The table can be made of two pieces of pasteboard as shown. Set it low enough to let the cloth and hand clear what drops when wiping. If cold solder surrounds the pipe when finished, melt it apart with the copper.

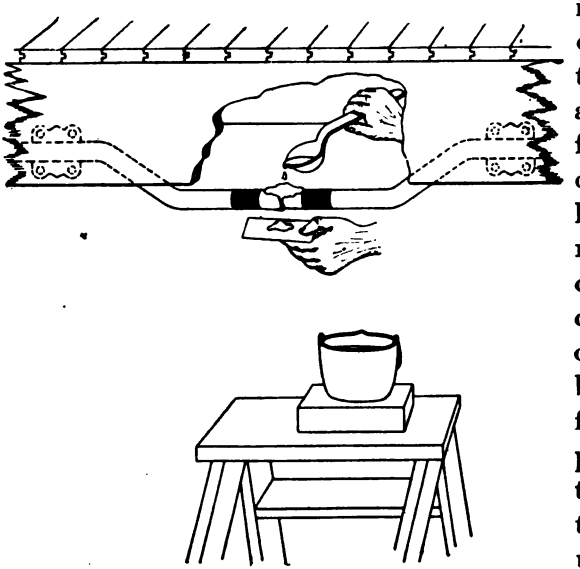


Fig. 33. Wiping an Overhead Joint

The *overhead joint*, shown in Fig. 33, is wiped in the same way as though it were on the floor. The position is a trying one, and the cloth and ladle are kept in place at a great disadvantage. A stiff cloth is best to get the heat with; while a second, more flexible and previously warmed, can be used in conjunction, to do the shaping and wiping. Some heat previously applied with the torch to the edges,

will shorten the time of getting the heat, and save the wrists and fingers from cramp and excessive tiring. Some provision for straightening the line is necessary, if a straight shoot is too high to wipe. Sometimes the surplus pipe is *snaked* into one horizontal plane with proper incline so that the pipe will drain, and is supported by a shelf

SECTION OF SWIMMING POOL SHOWING WATER HEATER AT THE RIGHT OF POOL WALL

Courtesy of Federal-Huber Company, Chicago

DRAINAGE WORK AND VENTING

DESIGN AND CONSTRUCTION OF DRAINAGE SYSTEMS

Definitions. The term *house drain* may be applied to the pipe which receives the total discharge from any fixture or set of fixtures, within any building, and which carries or conducts it to the house sewer. The discharge may or may not include rain water.

The term *house sewer* is applied to the pipes, usually composed of vitrified clay, which begin about 4 feet outside the foundation wall of the building and connect the house drains with the public sewer in the street.

The term *public sewer* is applied to the pipes laid in the streets and into which flows the sewage from all buildings and premises within the same curtilage.

The term *cesspool* is applied to an underground tank receiving the sewage from one or more buildings. Such a tank often is adopted where no public sewer exists.

Essential Features of Drainage System. An efficient system of drainage should embrace the following features:

(1) There must be no escape of liquids, solids, or drain air from any part of the house drain, branch drains, soil, waste, or vent pipes.

(2) All drains must be laid on a solid foundation, either natural or artificial, in straight lines from point to point, with adequate provision for cleansing at the highest point of each branch. The whole system must have an even, regular, and minimum fall.

(3) All drains must be large enough to carry off the maximum quantity of sewage, yet small enough to insure self-cleansing.

(4) The discharge of all greasy sewage from kitchen sinks, etc., must be intercepted from the drain by an approved type of catch basin or grease trap.

(5) The junction with the public sewer should be made by means of an approved oblique-hubbed junction pipe or by

concrete blocks set in Portland cement, and it should be the same size as the main drain.

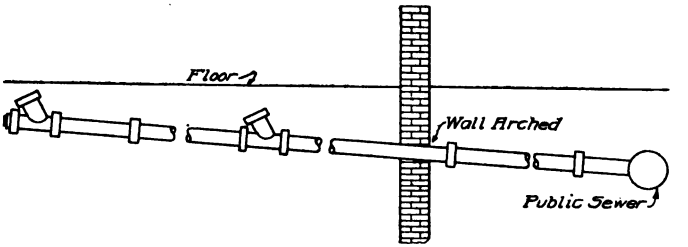


Fig. 1. Simple House Drainage System

(6) All drains should be capable of withstanding the hydraulic test to a head, or height, of 5 feet.

(7) Correct drainage plans must be kept for every building.

(8) In localities where a house or main trap is demanded on the system, the trap should be self-cleansing and provided with two accessible clean-outs.

(9) The drain from this point must have provision for the inlet and outlet of air in order to secure a proper air flush through the entire system.

Recognized Systems. (1) A system in which the house drain commences at the highest stack and passes direct through the foundation wall, connecting with the house sewer and thence to

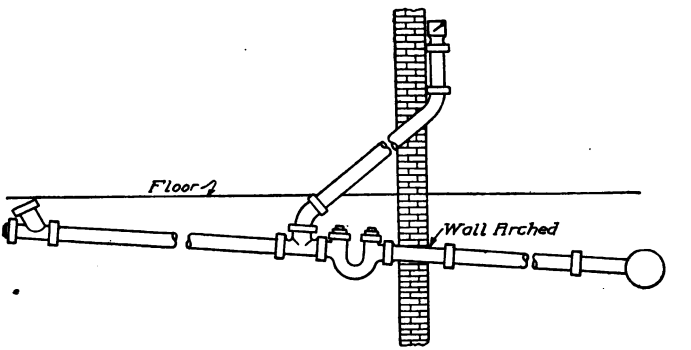


Fig. 2. House Drainage System with Intercepting Trap Inside Foundation Wall

the public sewer, is shown in Fig. 1. The main vent pipe is carried through the building and terminates in an increaser, about

eight inches above the roof. This vent acts as an outlet for the sewer gases which would otherwise accumulate in the public sewers.

(2) A house drain aerially disconnected from the sewer by an efficient self-cleansing intercepting trap placed inside the foundation wall is shown in Fig. 2. On the house side of the trap, provision is made for a fresh-air inlet which secures a thorough air flush throughout the whole system, eventually escaping through

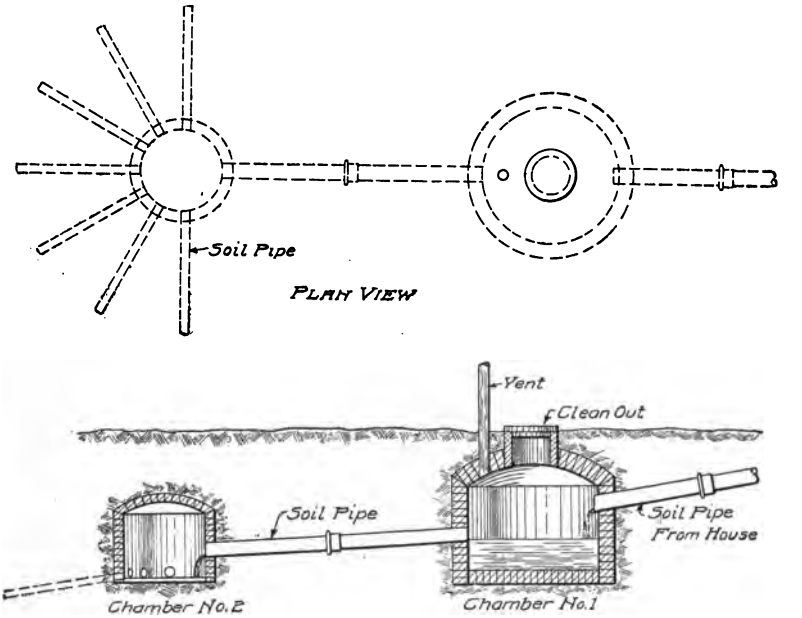


Fig. 3. House Drainage System with Cesspool Connection

the terminal of the main vent pipe. With this method, a separate system of ventilation for public sewers is necessary.

(3) Where no public sewer exists and the drainage from a country building has to be disposed of, the house drain usually is disconnected, as in (2), and the house sewer connects with a cesspool, Fig. 3, which serves the useful purpose of liquefying all the sewage.

Kinds of Pipe. Two kinds of pipe are used for drainage work, namely, vitrified clay and cast iron, the latter being coated internally and externally with pitch. Almost all sanitarians hold that cast iron is superior, for cast-iron pipe is capable of withstanding a greater

internal and external pressure than clay pipe. Furthermore, it is in longer lengths and, consequently, there are fewer joints; these, being made with lead and oakum, are more reliable. If any settling in the ground occurs, cast-iron pipe is not so likely to be fractured. If trees are about, their roots cannot penetrate the pipe or the lead joints. Cast-iron pipe is also free from fire cracks, flaws, lumps, and other imperfections which are found so often in clay pipe. However, clay pipe answers very well for house sewers outside of the building and is somewhat cheaper than iron pipe.

LAYING OF DRAINS

Foundation and Fall. It is imperative that all drains be laid on a good foundation, either natural or artificial. An artificial foundation may be formed of Portland cement or lime concrete, with holes cut in it to receive the hubs of the pipe. This insures the pipe having an even bearing over its entire length. It must be laid with an even fall, that is, the drains must not have a fall of 1 in 100 for 20 yards and then dip with a fall of, say, 1 in 5. The minimum fall for a drain 4 inches in diameter usually is taken as 1 in 100. An easy rule for setting out the necessary fall for drains is as follows: *Multiply the diameter of the pipe in inches by 10 to find the length in feet which should have a 1-foot fall.* For example, when using a 6-inch drain, $6 \times 10 = 60$, or 1 foot in 60 feet represents the proper fall.

If the proper fall cannot be obtained, an automatic flush tank should be erected at the head of the drainage system to operate automatically and thus discharge a large bulk of water down the drain at regular intervals. Should the drains be laid at too steep a gradient, the liquids will flow off too quickly and leave the solids behind to choke the drains. The automatic flush tank should be provided also in a case of this kind. It is always better to have a large volume, say, 200 gallons, discharged down the drain once a day than to have 30 gallons discharged seven times a day.

Velocity and Discharge. The velocity of flow through a drain 4 inches in diameter should be from 3 to $4\frac{1}{2}$ feet per second, while a drain 6 inches in diameter is considered to have a self-cleansing

velocity when flowing at 2½ to 3 feet per second. The larger the drain the less fall it requires and, consequently, the velocity of flow decreases.

The maximum flow occurs in drains running 0.813, or $\frac{13}{16}$ full, not full as commonly supposed, owing to the friction caused by the large surface of drain pipe and small depth of sewage in the remaining part of the pipe. It is for this reason that sewers often are constructed egg shape, which gives a good depth of sewage with a minimum amount of friction. The maximum discharge does not coincide with the maximum flow but occurs at 0.95, or $\frac{15}{16}$ full.

Size of Drains. All drains should be of the smallest diameter consistent with the work to be done by them. This is a very important item for, in making inspections of old drainage systems, 9-inch and 12-inch drains are found frequently even in small houses. A diameter of 6 inches is large enough for any main drain. The following rules are used to find the diameter of a main drain to carry off the effluent from a number of branch drains: (1) Circles are to one another as the squares of their diameters; therefore, we can take a 3-inch, 4-inch, and 5-inch drain and find the diameter D of a main drain whose area will equal the combined area of the three pipes. Then

$$D = \sqrt{3^2+4^2+5^2} = 50 = 7.1 \text{ inches, size of main drain}$$

(2) By geometry, draw a line 3 inches in length, construct a line 4 inches long at right angles to the first one and join the extremities of these two lines by a third (called the *hypotenuse*, the third and longest side); next draw a line 5 inches long at one extremity of and at right angles to the hypotenuse and once more complete the triangle by drawing the hypotenuse. The length of this last line will be 7.1 inches, the size of the main drain required.

Provision for Settlement. Where the drains pass under walls, an arch should be constructed in the brickwork and one inch of asphalt should surround the pipe, otherwise settlement is likely to occur and damage the pipes. The correct method is illustrated in Fig. 4.

It often happens that drains have to pass through basements above ground level. They should always be constructed of iron

and should be adequately supported at regular intervals by brick pillars or hung from the ceiling joists on iron hangers. Of course, these drains must have the required fall and must be absolutely water tight and gas tight.

Main Trap. There is a diversity of opinion on the question of the main, house, intercepting, or disconnecting traps. Many authorities argue that the trap should be abolished and that the drains should discharge directly into the sewer.

On the other hand, it is true that this trap checks the flow of sewage and often causes a stoppage in the house drain; where the trap is installed, a regular system of sewer ventilation must be devised. Again, if we abolish the trap, the public sewers are

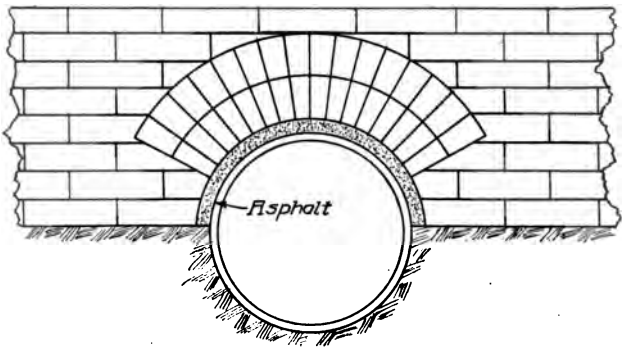


Fig. 4. Construction for Drain Pipe Passing under Wall

ventilated efficiently through the house drain and main vent in every building, and with such a large number of openings, or vent pipes, foul gases have little or no time or opportunity to accumulate in the public sewers and are highly diluted with fresh incoming air.

There are always two sides to every question, however, and in old buildings with obsolete sanitary fixtures, connections, and workmanship, coupled with inadequate venting, it is better, perhaps, to exclude the air from the sewers by means of an efficient intercepting trap than to have the foul gases pouring into the buildings and contaminating the air of the rooms. In many parts of Canada, it is compulsory to intercept the house drain from the house sewer. It has been found that extremely cold air rushing

direct through an untrapped system freezes the water in the traps under the fixtures.

Wherever the trap is adopted, it must be of good shape and must be self-cleansing. The trap should hold a small quantity of water and its seal should be deep. It should be installed just inside the foundation wall and should be provided with two accessible clean-outs.

Ventilation of Drains. The drains in every building must be ventilated, that is, a current of fresh air must pass continuously through the system in order to obviate siphonage, back pressure, etc. This is accomplished by providing an inlet for fresh air at the lowest point, an outlet being placed at the head of the system.

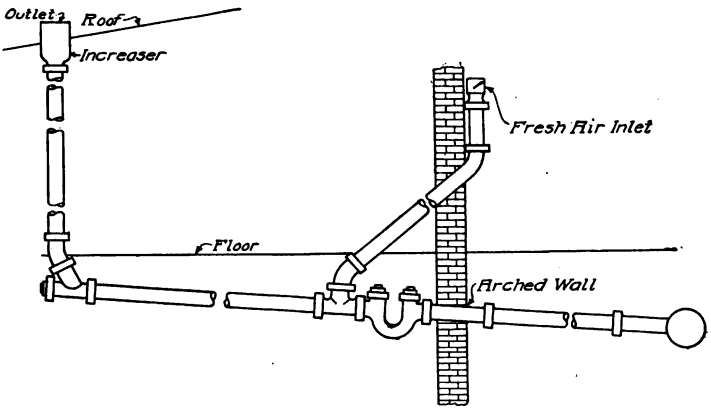


Fig. 5. Layout Showing Ventilating Pipes in House Drainage System

If the house trap is not used, an open grid is provided on the sewer manhole at street level, through which the fresh air enters, eventually escaping through the terminal of the vent shaft above the roof.

Where the house trap is installed, it is usual to connect the fresh-air inlet immediately on the house side of the trap through a Y or similar fitting. The fresh-air inlet should never be less than 4 inches in diameter and should be the same size as the main drain; it should be carried up the external wall, say, 7 feet above ground level, Fig. 5. A silk-flap inlet can be provided at this point which admits fresh air freely but prevents foul air escaping in the case of a down draft.

The main vent should be carried up undiminished, with as few bends as possible, to a height of 8 inches above the roof. This is just high enough to prevent the rain splashing from the roof into it. Some authorities prefer the vent to pass 2 or 3 feet above the roof, but this only exposes a large area of the pipe to cold and frost during the winter months which, of course, cools the escaping air, makes it heavy, and tends to check the up-current. For the same reason the terminal of this vent pipe must be increased at least one inch in diameter, 12 inches below and 8 inches above the roof. This increase enables the ascending air inside the pipe to expand and become lighter than that outside, thus assisting the circulation. In every instance, the outlet should be at least 15 feet from any window.

At one time cowls and ventilating hoods were placed on the terminals of vent pipes to prevent down drafts, yet the best forms diminished the air current passing through the pipes 40 per cent. If trees and birds are in close proximity, the outlet should be furnished with a copper or galvanized-iron wire basket.

The correct installation of the trap, with fresh-air inlet and outlet passing through the roof is shown in Fig. 5.

Separate Systems. Where great difficulty is experienced in disposing of the sewage, the rain water is sometimes conducted away by independent drains which discharge into the nearest stream or water course, while the sewage from water closets, bathtubs, lavatories, sinks, etc., is carried directly into the public sewer or disposed of by bacteriological treatment. In such a system, both drains and sewers are likely to become choked as the scouring effect of the rain water is considerable. Again, the sewage is highly concentrated and is very difficult to treat. The method cannot be considered a very satisfactory one and should only be recommended in rare instances.

Junction with Sewer. All connections between the house sewer and the public sewer should be made with suitable junctions and bends. Connection with brick sewers should be made by means of proper junction blocks set in Portland cement. They should be fixed about two-thirds the height of the sewer above the invert. If fixed at a lower level, there is always danger of the drain becoming choked.

Catch Basins. As already mentioned in the article on "Sanitary Appliances", all greasy water must be excluded from the drainage system.

Some municipalities will not even permit the use of a grease trap unless the building covers the entire lot and there is no alley or other place to build a catch basin.

The grease from all kitchen sinks and restaurants must be congealed or solidified before passing into the drain and, to accomplish this end, a catch basin is constructed of brickwork, concrete, or iron. The smallest size should be 30 inches internal diameter at the base and may taper to 22 inches at the top. The opening at the top should be 16 inches and should be covered with a heavy lid of iron or stone. If a flag, or stone, is used, it must be at least 3 inches thick. The bottom of the catch basin should be at least 2 feet below the invert of the outlet to the sewer, and the outlet should be trapped to a depth of 6 inches below the invert of the outlet to the sewer to prevent the escape of grease. A hood, or trap, of brick and cement mortar or a hood of concrete or cast iron may be used for the purpose. The invert of the inlet to the catch basin for kitchen waste should not be less than 2 feet 6 inches above the bottom of the catch basin, Fig. 6.

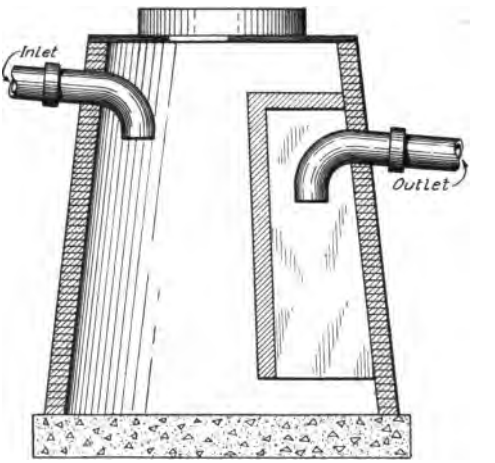


Fig. 6. Typical Section of Catch Basin

The rain-water conductors can connect directly with the catch basin which, during rainfall, helps materially to cool the water and congeal the grease.

DRAINAGE OF VARIOUS BUILDINGS

Basements. With low-lying basements, back pressure and consequent flooding are always likely to occur. However, this may

be obviated by the adoption of a suitable trap, Fig. 7. In the event of a flood, the copper ball rises and rests on the rubber seating which makes a water-tight joint. As soon as the flood

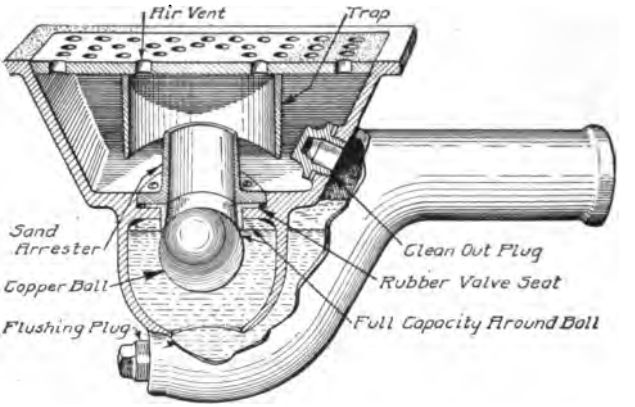


Fig. 7. Ball Trap for Preventing Flooding of Basements

subsides, the pressure is relieved and the ball follows the level of the water, but cannot pass through the trap. It will be observed that provision is made for rodding, cleansing, and flushing the trap.

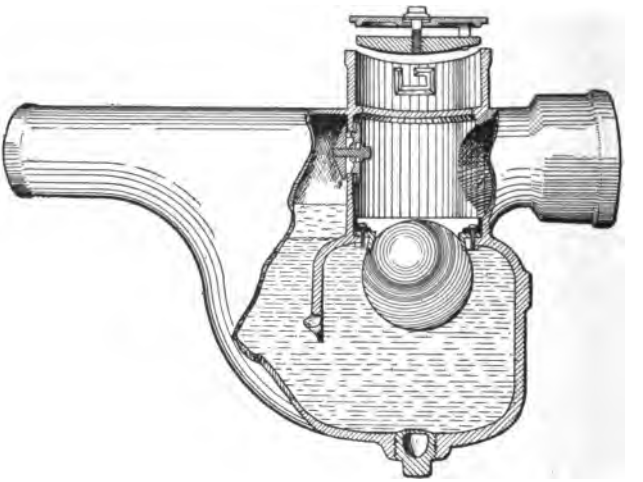


Fig. 8. Ball Trap for Disconnecting House Drain from House Sewer

A similar trap, suitable for disconnecting the house drain from the house sewer, is shown in Fig. 8. This, if permissible, usually takes the place of the house or main trap in those buildings where

back pressure is anticipated. It is installed just inside the foundation wall and a fresh-air inlet is provided, on the house side of the trap, which permits a continuous current of air to pass through the entire drainage system even when back pressure closes the trap. Obviously, no air can pass through the system if the valve is closed and the house fixtures are flushed.

Use of Sewage Pump or Cellar Drainer. Where the level of the outfall of a sewer for either an individual house or a community is below the level into which the final discharge must be

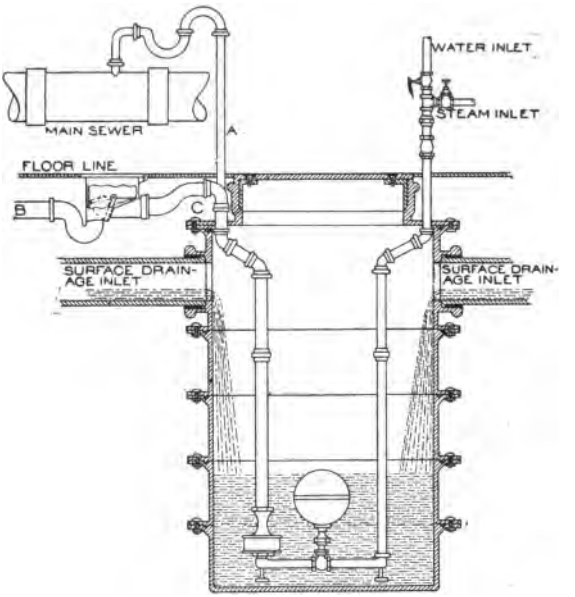


Fig. 9. Well for Collecting Surface Drainage from Subcellars, etc., below Main Drain, into Which It Is Subsequently Lifted and Discharged

made, it is necessary to use a sewage lift, or pump, to raise the matter to a point where gravitation will again take care of the flow. These lift pumps may be had suitable for either large or small installations. For subcellars or other points below the level of the main drain, surface drainage may be assembled in a well as shown in Fig. 9; and from there, by means of a cellar drainer operated by steam or water, it may be lifted automatically and discharged into the drain, as shown in the diagram. The well is composed of metal rings about 30 inches in diameter bolted

together. One section is provided with pipe hubs for entry of the surface drain pipes and the cap is arranged with a manhole opening and cover. If the drain into which the water is discharged is subject to reverse currents from tide or flood water, then a trap, with a tide-water valve, arranged as shown between *B* and *C*, is used; otherwise, a simple trapped connection pipe *A* leads the discharge water into the sewer and the work shown from *B* to *C* is omitted.

Stables. The principles which should govern stable drainage being precisely the same as those applied to ordinary house

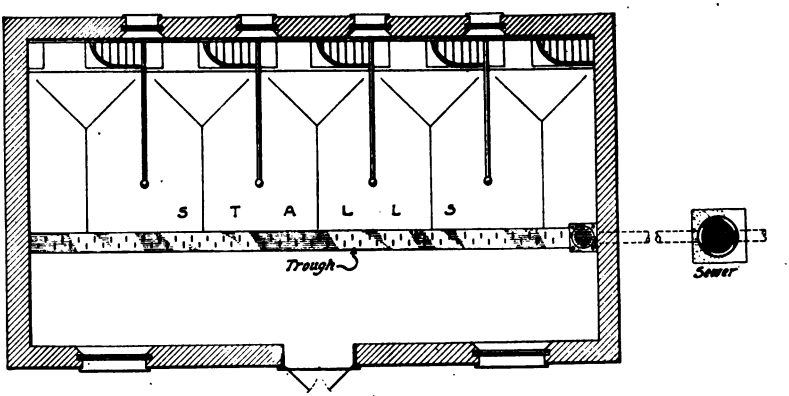


Fig. 10. Plan of Stable Showing Good Drainage System

Fig. 11. Details of Covered Channel in Stable Design, Fig. 10

drainage, there would be no need to mention it specially were it not that, owing to the presence of straw and the desire to retain all manure for agricultural use, a completely different set of appliances is necessary.

Stable floors usually are formed of grooved concrete or paving bricks laid so as to fall to narrow channels covered with iron gratings. As indicated in Fig. 10, these channels commence about the middle of the stall and fall toward the back, where they empty into a collecting channel in the passage-way behind; and this, in turn, empties directly into a catch basin, usually fixed in a

convenient position outside the building, Fig. 10. The covered channel with a lifting grating is shown in Fig. 11. It will be observed that the fall is provided in the invert of the channel and so is independent of that of the stable floor, to which, if necessary, it may be contrary.

Cow Sheds. The drainage systems of cow sheds are arranged in a similar manner to those of stables, only a feeding passage and vitrified-clay feeding troughs should be provided, Fig. 12. A concrete shallow open gutter, or channel, conducts the semi-

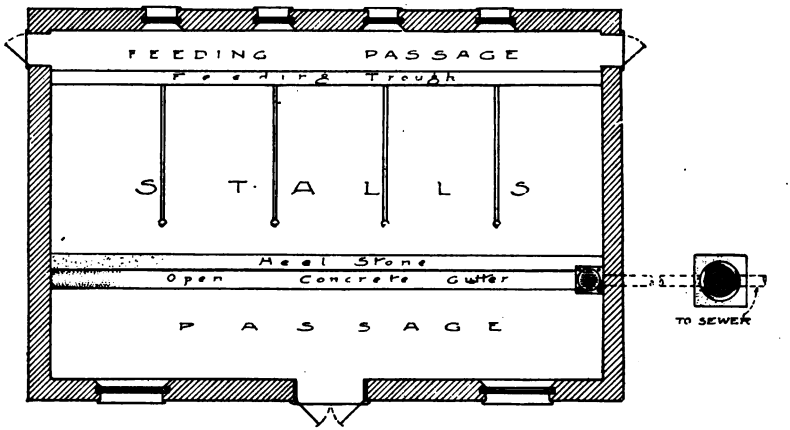


Fig. 12. Plan of Sanitary Cow Sheds

liquid sewage to a grid and drain at one end of the building, and this, in turn, leads to the catch basin.

Garages. Extraordinary care has to be exercised in the drainage of garages, not only from a sanitary point of view, but also to comply with the fire ordinances of cities. There is always grave danger of explosions occurring in the public sewers if, by any lack of precaution, gasoline and gasoline vapor should find its way into them in large volumes.

Every garage should have a system of triple catch basins through which all sewage must pass before entering the public sewer. These basins must be constructed of cast iron if installed inside the building and each unit must have a minimum diameter of 18 inches and a minimum depth of 24 inches. Each unit should be trapped so as to allow a water seal of not less than 10

inches, and each unit must be connected to a standard galvanized vent pipe of not less than 2 inches, and arranged so as to allow not less than 4 inches of air space between the water line in the basin and the bottom of the vent opening. The inlet to the catch basin should have not less than a 4-inch water seal. The cover of the basin must be air tight and, if any sand basins empty into this system, they must not be trapped. In no case should rain leaders or conductors be used for venting this system. Fig. 13 shows the Wade system of drainage which embraces all the essential features mentioned above and has the endorsement

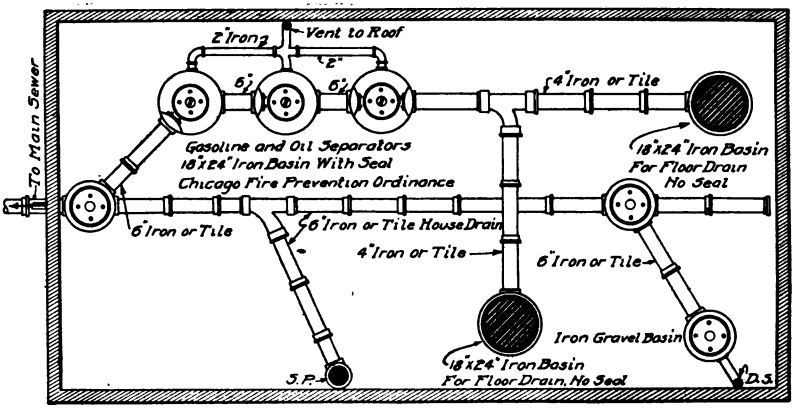


Fig. 13. Layout of Wade System of Drainage for Garages

of the sanitary chief and the fire prevention chiefs of the city of Chicago.

Country Houses. There are numerous country houses remote from any public sewers, and we are called upon to devise some method of carrying away the sewage speedily and without contaminating the air, soil, or water. It must be remembered that most of these houses depend upon wells for their water supply, and great care should be exercised to avoid the possibility of the sewage polluting the water.

Methods of Drainage. There is always plenty of land available and, for the ordinary type of house, one of the following methods of drainage can be adopted:

In those buildings where the water closet is fixed outside, the sewage from sinks, lavatories, etc., may be collected in an auto-

matic flush tank after having passed through the house drain and the intercepting trap. The operation of the tank discharges the sewage through tightly jointed vitrified clay pipes to a distance of 50 feet or more from the building and well away from any water supply. The sewage then enters subsoil drains composed of unglazed stoneware pipes without hubs and jointing material. The pipes are laid in every direction and about 2 feet below the surface of the ground. The sewage percolates through the open joints and is sucked up by the earth even in wet weather. About every 18 months these drains should be dug up and re-laid; other-

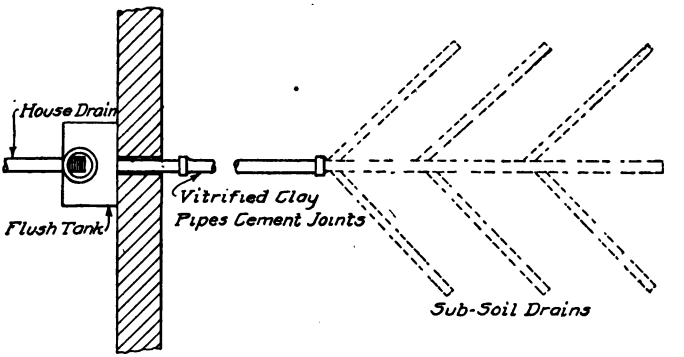


Fig. 14. Layout for Sewage System for Country House Where No Public Sewers Are Available

wise the earth will become sewage sick and will not perform its function properly. This method is illustrated in Fig. 14.

Another method is to carry the sewage through tight pipes to a leaching cesspool situated at least 50 feet from the house and 100 feet from the source of water supply, Fig. 15. The leaching cesspool is merely a hole dug in the ground; the sides are built up with bricks and no jointing material is used, consequently percolation occurs through the bottom and the open joints. The top is covered with a substantial flag or is sometimes arched over with brickwork.

In those buildings having a regular water supply but no sewers, and where water closets are used inside of the house, the difficulty is solved by means of a light-tight and air-tight cesspool. The sewage is carried to the cesspool by means of cement-jointed vitrified clay pipes after being intercepted by an efficient trap

installed just inside the foundation wall. This system is similar to the leaching cesspool, only percolation is not permissible. It is produced by digging a circular pit of the required size in the ground and forming the bottom with Portland-cement concrete. The sides should be built of hard impervious bricks with cement joints. The whole of the cesspool should be backed with 9 inches of well-puddled clay and provided with a cover. Access of air is provided for by a single pipe carried up a tree or any convenient place to a height of 10 feet. It is provided with an overflow placed at a level slightly lower than the intake. This discharges

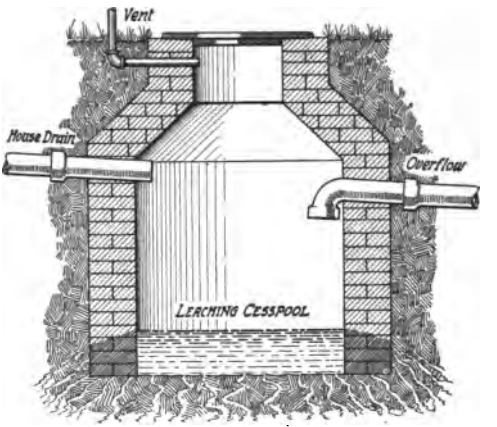


Fig. 15. Section of Leaching Cesspool

into a stream, if one should be near, or into another leaching cesspool. This method is illustrated in Fig. 3.

METHODS OF TESTING DRAINS

The testing or examination of drains amounts to the application of certain tests for the determination of soundness. Four different methods of testing drains are employed in different parts of the country, namely, the smell test; compressed-air test; smoke test; and water test.

Smell Test. The smell test consists in adding a tablespoonful of oil of peppermint to a bucket of water which is poured down the vent, soil pipe, or drain, as the case may be. The oil has a very pungent odor which is freely emitted if any leakage exists in any part of the system. However, this test is of little use in

detecting leaks under the ground, and in pouring the liquid down a vent pipe, a quantity may possibly find its way down the outside of the pipe and mislead the inspector.

Air Test. The compressed-air test is not extensively used. A pneumatic machine is necessary for this purpose and consists of a force pump, such as is used for inflating a football, by means of which air is pumped into the drains. An attachment with a pressure gage and a safety valve, to indicate the pressure and to avoid too great a pressure, forms part of the equipment. If a leak exists in a part of the system, it will be readily shown on the pressure gage, but as the escaping air cannot be seen nor smelt and rarely can be heard, the air test cannot be considered a very helpful one.

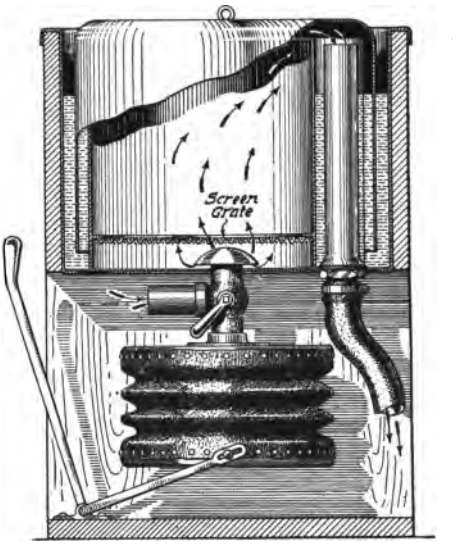


Fig. 16. Part Section of Pumping Apparatus for Making Smoke Test of Drains

Smoke Test. The smoke test consists in filling the drain or soil pipe with smoke which, in most cases, will find its way through any leak, faulty joint, cracked pipe, or broken seal of the trap; and as the smoke can be both seen and smelt, the exact site of the leak can be located. The smoke may be forced into the pipe by a specially prepared rocket or, better still, by the aid of a machine and a pumping apparatus, Fig. 16. The smoke test is the best way of testing the system, when the fixtures are installed, and is also the best test for soil and vent stacks in very high buildings which would not permit the water test being applied.

Water Test. The water, or hydraulic, test is the only trustworthy one for underground drains; but it must be remembered, however, that water exerts a considerable amount of pressure, and a greater head of water than 20 feet should never be employed as otherwise serious damage may be done, especially if the drains

are of vitrified clay. In this method, the first operation is to plug up the lower end of the drain with a suitable testing plug, Fig. 17, and fill the drain with water to a 5-foot head. If the water level remains constant for about an hour, the drain may be considered satisfactory. If it will not fill or the level falls rapidly, there is a leak, and it becomes necessary to open up the ground and repair the defect or, in some cases, perhaps, to re-lay the drain.

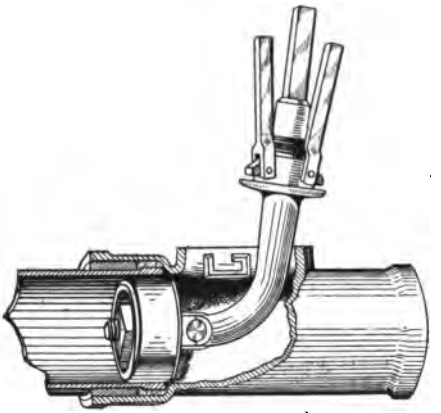


Fig. 17. Part Section of Plug for Drain Testing

REPORTS OF INSPECTION

Recommended Form. On concluding an inspection of a residence or public building, a report should be sent to your customer. There are numerous ways of arranging reports, but the following is one which seems the most intelligible to the average person unfamiliar with sanitation.

REPORT upon the Drainage and Sanitary Fixtures of.....
.....House, ...Street, ...City, in accordance with (verbal or written) instructions, received from.....
..... on the ..... day of ....., 19.....

Address of Inspector.....

Date.....

Item	Report	Recommendation
Sewage outlet	Discharge into sewer	Satisfactory
Drains	9-inch vitrified clay pipe, joints made of clay	Lay 4-inch cast-iron pipe with oakum and lead joints
Control	No means of access	Insert clean-outs as shown on plan
Ventilation	None	Insert inlet on house side of trap and carry main vent 8 inches above roof and increase to 6 inches
Soil pipe	Cast iron (heavy)	Satisfactory
Rain-water conductors	2 inches in diameter, connected directly with drains	Replace with 4-inch pipe and connect at *A* and *B* on plan

Item	Report	Recommendation
Surface traps	Insufficient seal	Substitute traps with 2½-inch depth of water seal
Water closets	Siphon-jet type	Satisfactory
Bathtub	Enameled iron of good pattern. The overflow is leaking, etc., etc.	Take out overflow and repack with rubber gasket

VENTING

Discussion of Terms Used. *Main Soil Pipe.* The main soil pipe receives the discharge from one or more water closets, with or without other fixtures. The other fixtures may include the waste from bathtubs, lavatories, urinals, etc.

Branch Soil Pipe. Any pipe receiving the discharge from one or more water closets, with or without other fixtures, and leading toward and connecting with the main soil pipe, is called the branch soil pipe.

Waste Pipe. The waste pipe receives the discharge from any fixture or fixtures other than water closets.

Main Soil Vent. The main soil vent is a continuation of the main soil pipe and commences above the highest fixture. It should be carried up the same size or diameter as the soil pipe and be increased at least one inch in diameter in passing through the roof. It must extend at least one foot below the roof and 8 inches above it and should terminate at least 15 feet from any window.

Main Vent. The main vent is a pipe provided to ventilate a system of piping and to which the re-vents are connected. This vent should be run separately through the roof or should be connected with the main soil vent 3 feet above the highest fixture. In the case of high buildings where the vent has to pass through five or more floors, it must be at least 3 inches in diameter and must pass independently through the roof and be re-connected to the main soil or waste pipe by a Y-branch below the lowest fixture in such a manner as to prevent any accumulation of rust or condensed water which would diminish the size of the pipe and eventually render it useless for the purpose for which it was installed. If the fixtures are on one floor only and no other fixtures are on the floors above or below, this re-connection may be dispensed with.

Re-Vent. The pipe taken directly off the trap, or as close to it as is practicable, and connected with the main vent is known as the re-vent. The object of this pipe is to provide a column of air on the sewer side of the trap and to prevent the water seal of the trap being broken by siphonage or back pressure.

Fig. 18 illustrates a typical system of piping embracing the above definitions.

Venting in General. No hard and fast rule can be laid down in the matter of venting.

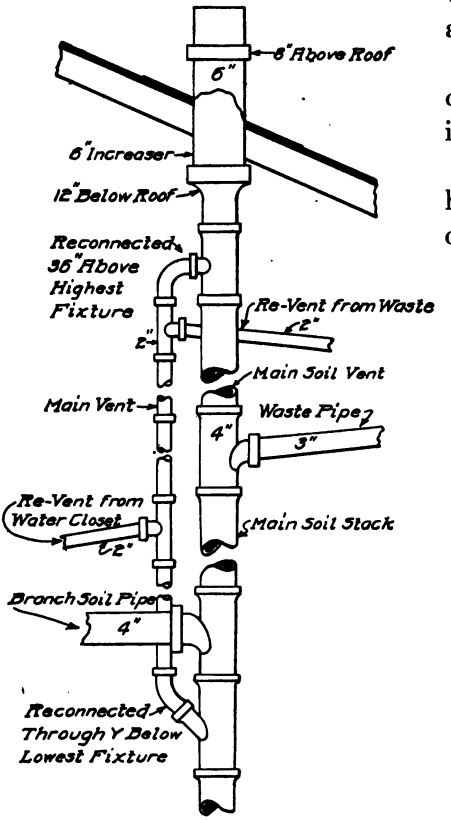


Fig. 18. Layout of Pipes Illustrating Venting Terms

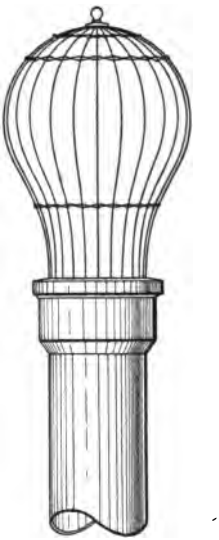


Fig. 19. Wire Basket for Venting Outlet

Different states have different codes, and authorities in one state advocate one system while other authorities in adjoining states condemn it.

In many localities the main soil vent passes through the roof without being increased, while in others an increaser must be provided to conform with the ordinances. The object of the increaser is to prevent the terminal being closed by hoar frost. Again, in cold weather, the heavy air at the terminal tends to

check the up-current if the vent is not increased. Obviously, these dangers are greater in 2- and 3-inch pipes, but no outlet should be less than 4 inches.

Not many years ago, it was customary to fix a ventilating cowl on the outlet, but it has been proved that the most efficient cowl procurable will diminish the up-current at least 40 per cent. If trees and birds are in close proximity to the terminal, a wire basket, Fig. 19, can be furnished.

Flashings. Vent flashings are devices, usually made of copper, for flashing around pipes; but the plumber will do well to command the skill necessary to manipulate sheet lead to suit conditions as he finds them. In any location where warm air will always be seeking an outlet from the attic through chance openings, the sleeve of the flashing may be made 2 to 4 inches larger

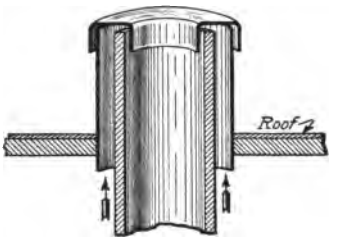


Fig. 20. Flashing Capped with Annular Ring of Lead

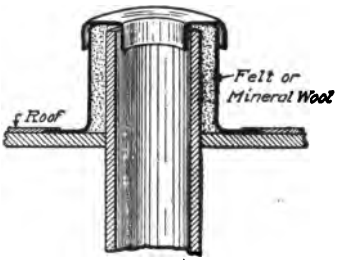


Fig. 21. Flashing with Mineral Wool or Felt Packing

than the outside diameter of the vent and capped with an annular V-ring of lead in the manner shown in Fig. 20. The cap ring need only be tacked to the sleeve with solder. The top edge of the sleeve should be notched or some other provision for the exit of air should be made. If, on account of braces or projections necessary to hold the pipe rigid where it passes through the sheeting, it is inconvenient to let the sleeve extend below the sheeting as shown in the illustration, it may terminate at the roof line. If the building is a storage warehouse or if, for any reason, the attic will not be very warm, or if conditions in winter favor cold air being drawn in through chance openings, then the method of flashing and packing the sleeve with felt or mineral wool, Fig. 21, should be employed. In all cases the vent and the flashing must rise above the possible snow level for flat roofs. The snow level on a steep roof will be less, but drifts may obstruct the vent if it is left at the snow level.

METHODS OF VENTING

Trap Ventilation. In order to secure a perfect working job, certain principles with regard to trap ventilation must be carried out, necessitating, in some buildings, a maze of pipe work which, to the uninitiated, looks like a senseless network, but which is, in reality, very necessary. Plumbers should be well versed in the fundamental principles underlying this work in order that they may be able to convince uninformed people of the imperativeness of efficient trap ventilation.

Loop Venting. A very satisfactory form of loop venting is shown in Fig. 22. This method is resorted to whenever the waste

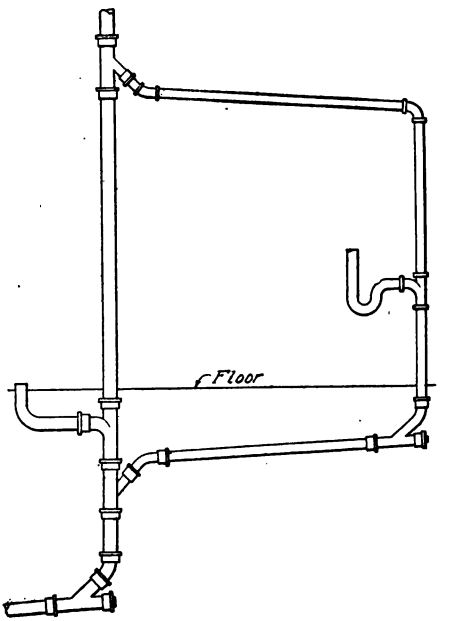


Fig. 22. Pipe Layout Showing Loop Venting Method

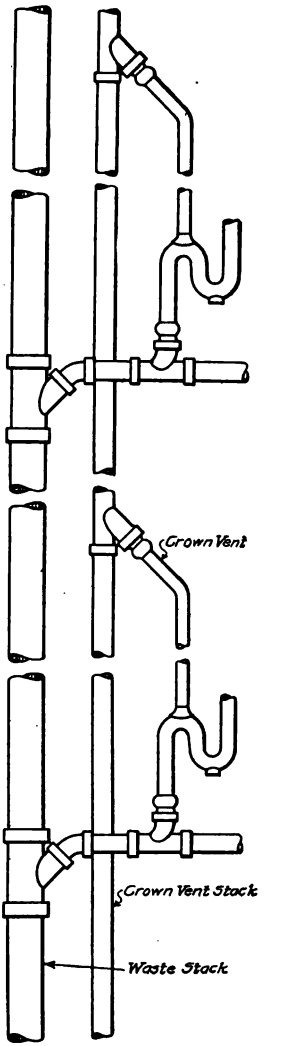


Fig. 23. Pipe Layout Showing Crown Venting Method

stack cannot come near the fixture. It is well to remember that every vent should be taken off the outlet of the trap and in no

case should it be a greater distance than 16 inches away. It will be noticed that in this method one-half the loop acts as a waste and one-half as a vent.

Crown Venting. In many localities the re-vent is connected directly with the top, or crown, of the trap, Fig. 23. Crown venting, as it is termed, is generally considered a very poor method for the sewage discharged through any sanitary fixture splashes directly into this air pipe and in a short space of time completely stops it up and renders it useless. For this reason, many ordinances prohibit crown venting and stipulate that all re-vents be connected at least 3 inches from the crown and not more than 16

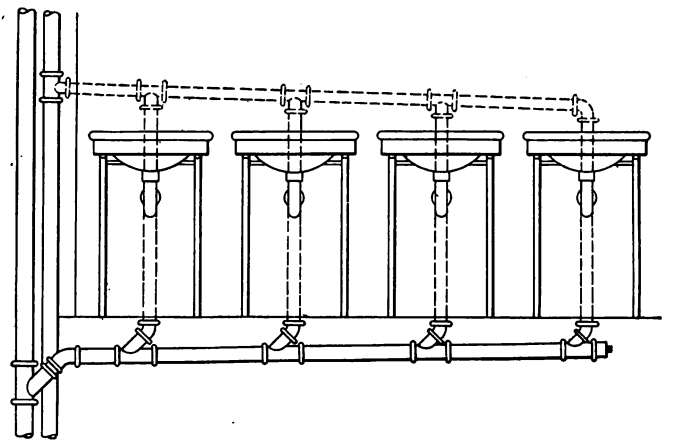


Fig. 24. Layout Showing Continuous Venting Method

inches from the trap. As already mentioned, if too great a distance intervenes between the trap and the vent, a vacuum is likely to be formed and siphonage may occur.

Continuous Venting. To obviate the stopping up of re-vents, the method known as continuous venting has been adopted and has given entire satisfaction. In the near future it doubtless will be recognized by every municipality as the most effective method. The system consists of a vertical waste and vent in one piece. The trap, which is usually a **P** or half **S**, is connected about 2 inches below the center of the outlet of the fixture through a fitting similar to a **TY**, yet it forms part of the fitting itself. The part below the trap is termed the *waste* and that above, the

re-vent. This method allows the vertical lines and the horizontal wastes and vents to be run behind the partitions with much less

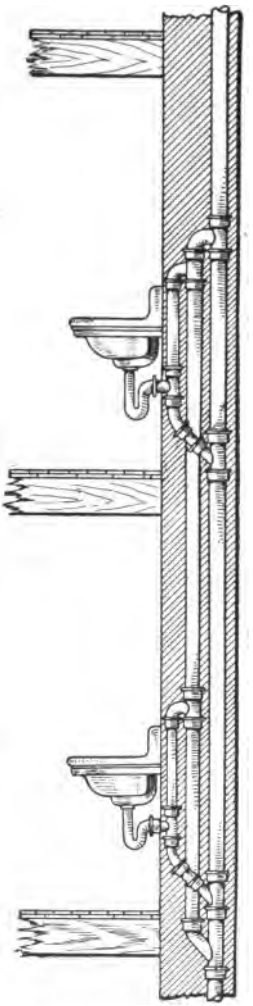


Fig. 25. Section Showing Continuous Venting Layout for Lavatories on One Side of Partition

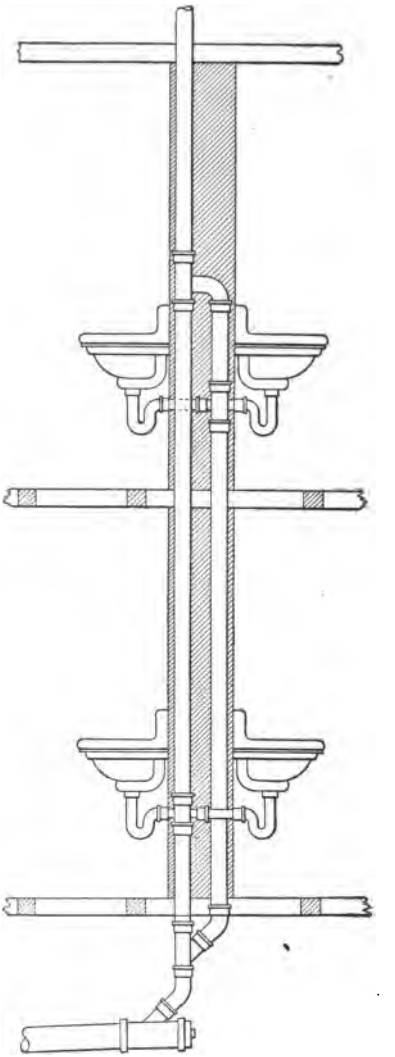


Fig. 26. Section Showing Continuous Venting Layout for Lavatories on Both Sides of Partition

labor and cost than any of the other methods. A typical example of continuous venting is shown in Fig. 24, where the four lava-

tories are vented on this principle. It will be observed also that a loop is formed. This method can be carried out without using any special fittings, as illustrated in Figs. 25 and 26, where lavatory basins are vented on one side of a partition and on both sides of it. Ordinary cast-iron pipe TY's, Y's, ¼'s, and other bends are installed which make an excellent piece of work.

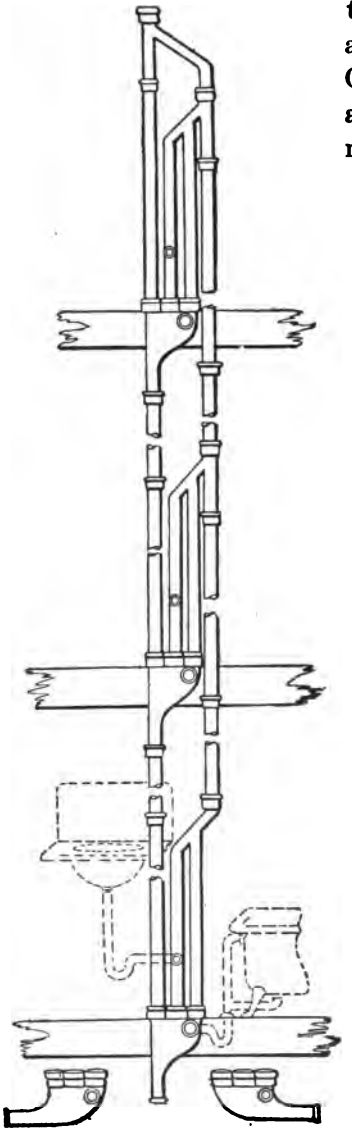


Fig. 27. Continuous Venting Layout Showing Use of Fruin & Walker Special Fittings

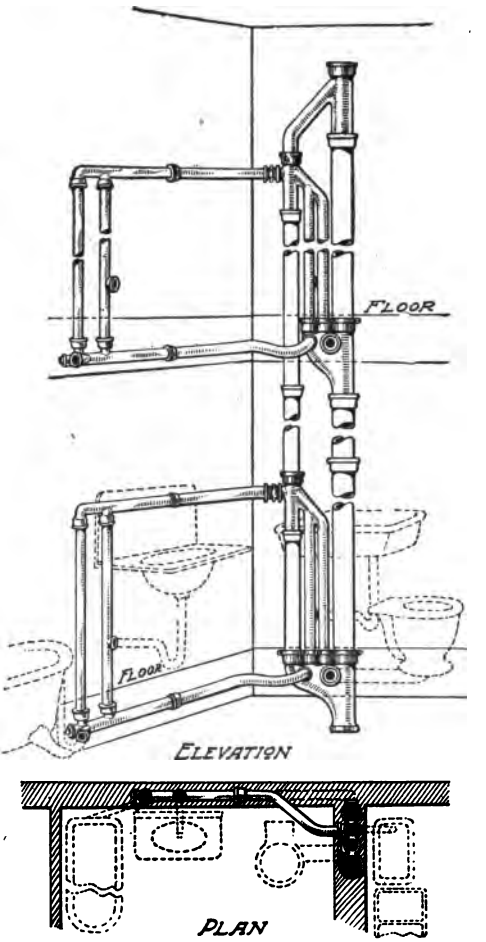


Fig. 28. Another Layout of Continuous Venting with Fruin & Walker Special Fittings

F. and W. Method. Messrs. Fruin & Walker invented a number of vent fittings which enable the continuous method to be carried out in a more compact and simplified form. These fittings are used extensively all over the country and are gaining in favor every day. The excellent features of this system can be summed up in the following points: (1) Siphonage is impossible; (2) rust cannot accumulate; (3) there is a positive circulation of air at all times through both the vent and re-vent; (4) when testing, every joint in the re-vent as well as the main stack is under water pressure, thereby reducing to a minimum the possibility of leakage of sewer gas; (5) the F. & W. fittings require less room between partitions than do other systems; (6) they are cheaper and, when properly connected, are practical, sanitary, and durable; (7) they occupy less wall space; (8) their curves and angles are easy and in the natural direction of the air currents, thereby decreasing friction and increasing the circulation of air throughout the entire system; (9) two typical installations are shown in Figs. 27 and 28, and Fig. 29 is a view of the piping installed in the Bronx jail, a fine example of compactness, owing to F. & W. fittings.

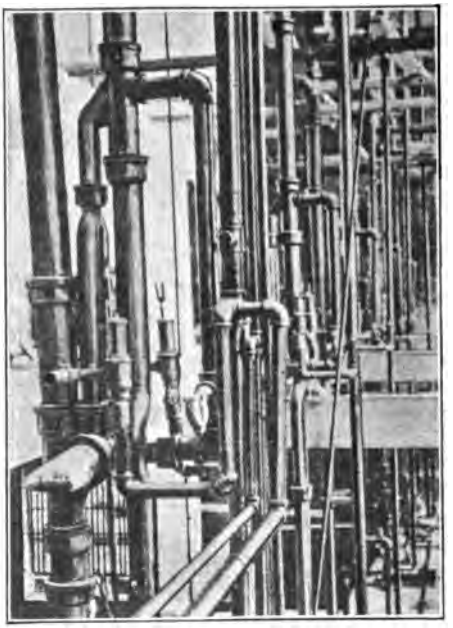


Fig. 29. Installation of Fruin & Walker Fittings in Bronx Jail

Circuit Venting. Another method of venting that is gaining favor each day is shown in Fig. 30. It is known as the circuit method and saves considerable piping and labor as it is not necessary to re-vent each fixture separately. In schools, offices, and public institutions, where batteries of water closets are installed, circuit venting answers admirably. However, not more than six closets should be on one line, since it is possible that, when the

two end closets are flushed, a vacuum may be formed between the two columns of water and the intermediate trap seals may be siphoned out.

Local Venting. The first and most important point to make in connection with the local venting system is that *a local vent will*

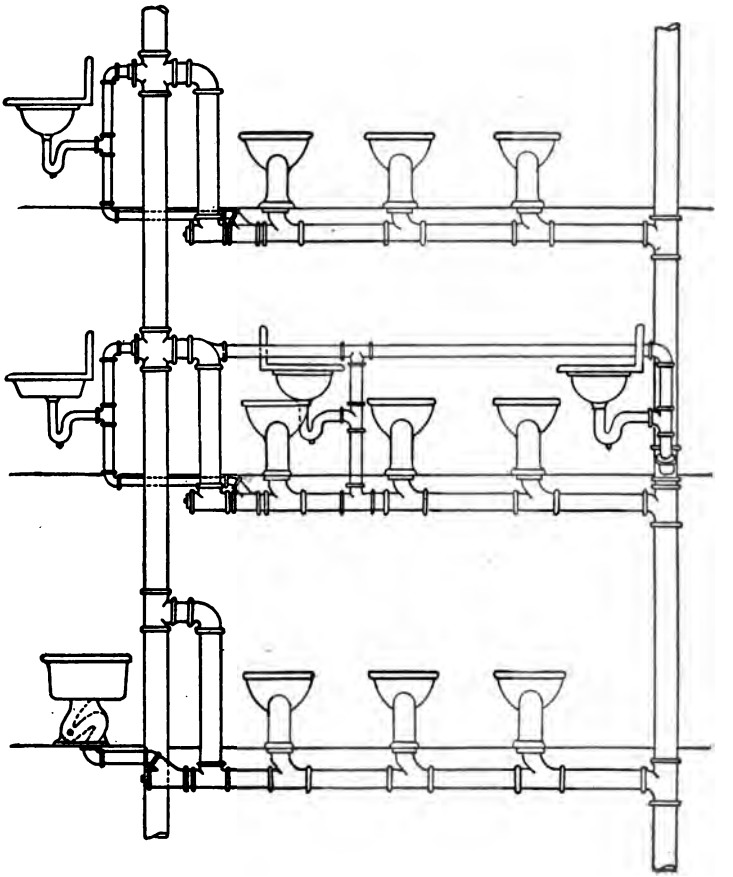


Fig. 30. Layout Illustrating Circuit Venting Method

not prevent siphonage. Local venting is applied only to water closets and urinals, the object being to carry off the foul gases which may accumulate in the basin. In this method, as in many others, there is a diversity of opinion as to its value. It is a very old method and not only has been discarded in many cities but is actually prohibited in a large number. At one time all local vents

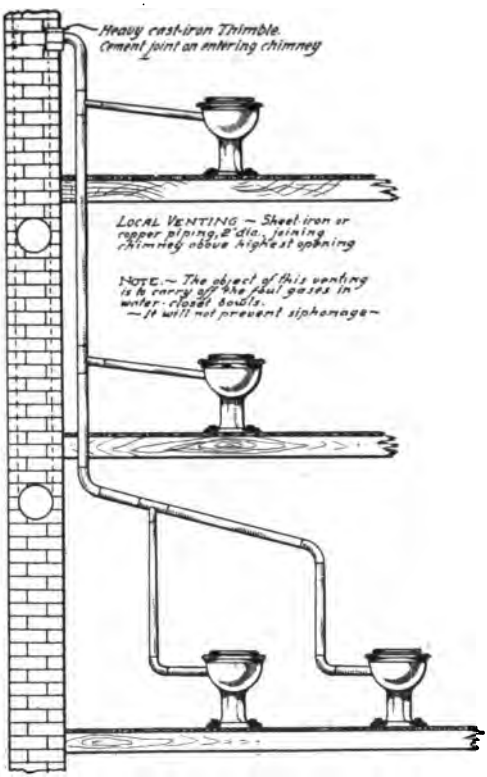

Heavy cast-iron Thimble. Cement joint on entering chimney
LOCAL VENTING — Sheet iron or copper piping, 2" dia. joining chimney above highest opening
NOTE. — The object of this venting is to carry off the foul gases in water-closet bowls. — It will not prevent siphonage —

Fig 31 Part Section Showing Installation by Local Venting Method

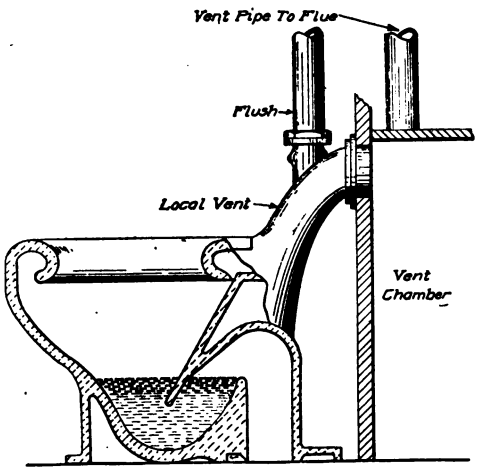


Fig. 32. Section of Closet Designed to Provide Local Venting

consisted of 2-inch sheet-iron, tin, or copper pipes, with slip joints, connected to the basin above the water in the trap and connecting with the chimney through a heavy cast-iron pipe, the joint being made with cement and this connection being made above the highest chimney opening, Fig. 31. Those who advocate this method claim that the warm air in the chimney acts as an exhaust and extracts the foul air not only from the basin but from the entire toilet room. If such is the case, it cannot be considered very sanitary to convey objectionable and dangerous gases through the building in sheet-iron pipes with slip joints. Now that the up-to-date water closets contain a large area of water in the basin which renders the excremental matter innocuous, and urinals of approved design are flushed automatically, it looks as though the method could be discarded. If local venting is to be adopted at all, the vent should form a part of the fixture, should be 4 inches

in diameter, and should discharge into a perfectly gas-tight chamber built for the purpose. This idea is illustrated in Fig. 32. The latest and what is considered the best method of applying local vents to urinals, Fig. 33, needs no explanation.

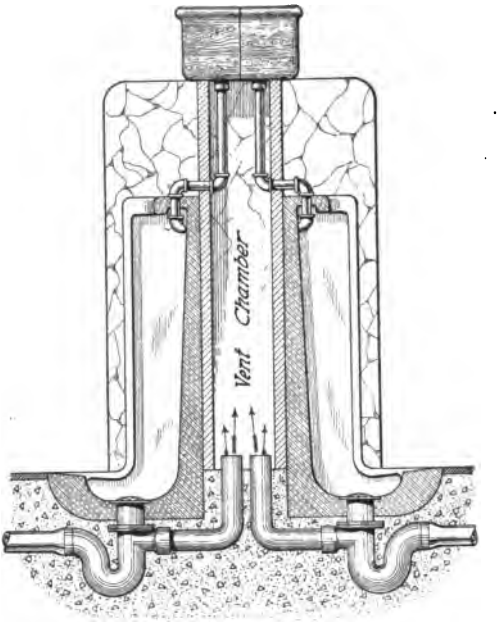


Fig. 33. Section Showing Local Venting Applied to Urinals

Rural District Venting. In rural districts where no codes are in existence, all forms of venting are often dispensed with, and anti-siphon traps simplify all the problems. These traps are also very convenient in awkward situations and when unusual difficulties present themselves. In Fig. 34 is illustrated an example of this kind, in

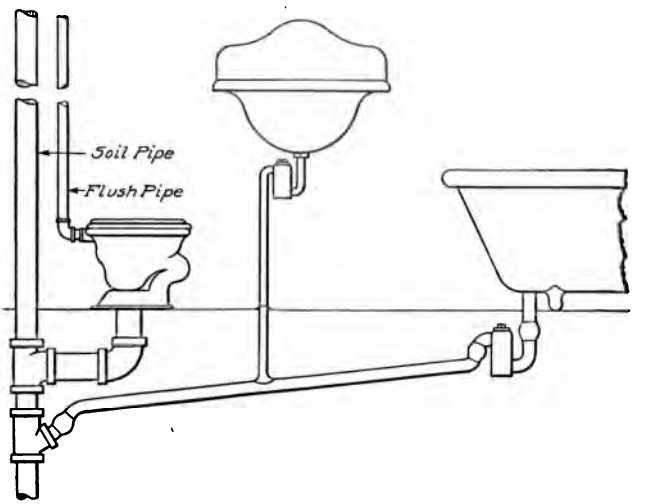


Fig. 34. Venting Layout for Rural District Using Nonsiphoning Traps

which nonsiphoning traps are used on both bath and lavatory without any form of crown or branch-line vents. In good practice, bath traps are placed where they are convenient to reach, having screw tops with hand-hole cover in full view at the floor level.

ROUGHING-IN

Wide Variation in Specifications. At this time no standard measurements for roughing-in can be quoted, owing to the countless makes and makers of fixtures. The makers of sanitary

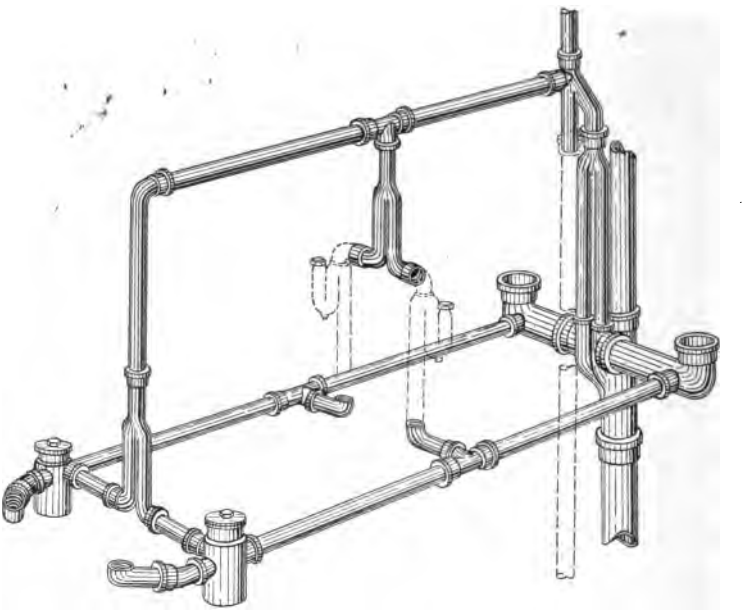


Fig. 35. Roughing-In Layout for Toilet Room of Flat Building

fixtures will not get together on this proposition, and if any measurements are published, they are only misleading. Most firms furnish all roughing-in particulars for each specific order and, under the existing conditions, this is the only trustworthy guide to follow. In Fig. 35 is illustrated a well-known line used in roughing-in for the toilet rooms of a flat building. Being drawn in perspective, the function and merit of every fitting shown is self-evident. Fig. 36 is a plan view of the roughing-in layout shown in Fig. 35.

Materials Used for Pipes, etc. There are three materials used for soil, waste, and vent pipes, namely, lead, cast iron, and wrought iron.

Lead Pipe. At one time lead was used extensively but, with the exception of a few short waste pipes, lead closet bends, and

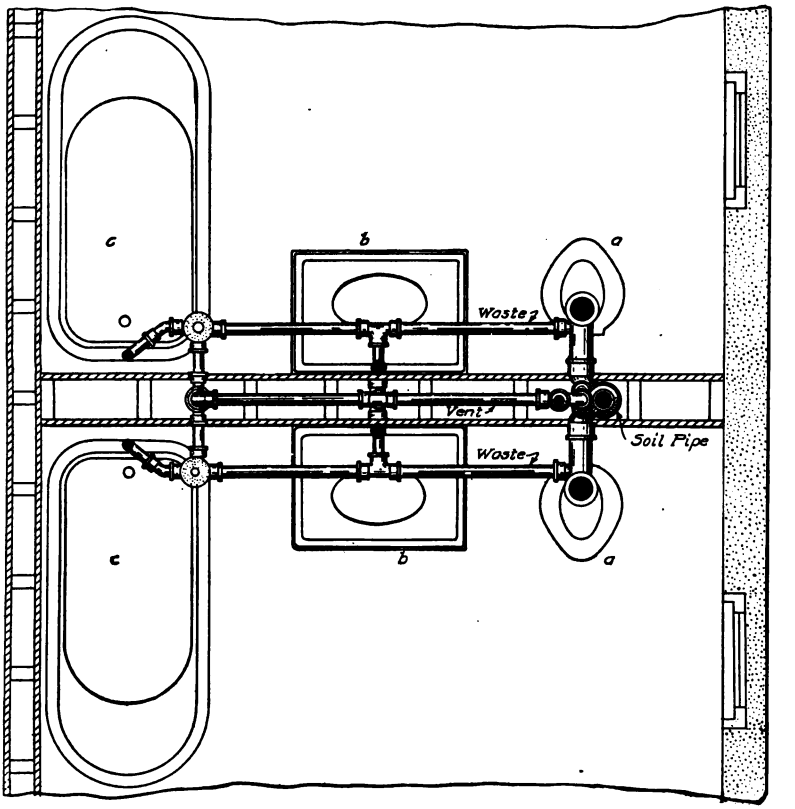


Fig. 36. Plan View of Layout Shown in Fig. 35

traps, it is now little used, and most large cities prohibit its use except in the case of old buildings and repair work.

Cast-Iron Pipe. Cast iron is the most popular material used in this country, but the pipe should be coated internally and externally with tar or asphaltum. It should be of uniform thickness and free from sand holes and other imperfections and the weight should be what is known as extra heavy. Table I gives the weight in pounds per lineal foot for the various sizes of pipe.

TABLE I

Weight per Lineal Foot for Cast-Iron Pipe

Internal Diameter (inches)	Weight (lb. per ft.)	Internal Diameter (inches)	Weight (lb. per ft.)
2	5½	7	27
3	9½	8	35½
4	13	10	45
5	17	12	54
6	20		

It is good practice to force each manufacturer to stamp his name and the weight per foot upon each length of pipe sent out. Where lead is permitted, all joints and connections should be made by means of wiped-solder joints, and where this pipe connects to iron, a stout brass thimble or soldering ferrule must be wiped on to the lead. One practice adopted to avoid joint wiping is to force a plain cast-iron thimble inside the lead in such a manner that the pipe or, more often, the closed bend is strengthened sufficiently to permit calking of the joint. If cast-iron pipes are used, the joints must be made with oakum and lead. After the molten lead has been run into the hub, it shrinks upon cooling and then must be calked to make a water-tight and air-tight joint. It is imperative that the oakum be calked perfectly solid into the hub before the lead is run in and that the joint be run full with one pour. Table II gives the amount of oakum and lead to be used for joints on various sizes of pipe.

Wrought-Iron Pipe. Buildings subject to vibration from operating machinery or other causes likely to loosen the joints must be equipped with wrought-iron pipe, known as the Durham system of plumbing. This method is now generally adopted not only in the above-mentioned buildings but on all high-class work where the initial cost is of secondary importance. The pipe should be coated with zinc, known as galvanizing, or should be tar-coated to protect the iron and to prevent corrosion. The joints are all threaded and jointed with red or white lead known as gas-fitters' cement.

Table III gives the weight in pounds per lineal foot for standard wrought-iron pipe, galvanized or tar-coated.

TABLE II

Weights of Oakum and Lead Needed for Cast-Iron Pipe Joints

Diameter of Pipe (inches)	Weight of Oakum (ounces)	Weight of Lead (pounds)	Diameter of Pipe (inches)	Weight of Oakum (ounces)	Weight of Lead (pounds)
2	2	1½	6	9	4½
3	6	2¼	8	11	6
4	7	3	10	13	7½
5	8	3¾	12	18	9

Pitch and Supports for Pipes. *Horizontal* soil and waste pipes should be prohibited. The minimum pitch should be taken at ¼ inch to one foot, making the pitch in the direction of the outflow and, with the exception of office buildings and factories, the horizontal distance should not exceed 20 feet. The foot of every vertical soil, rain, or waste pipe should be supported with bricks, stone, or concrete piers properly constructed to carry all the weight, if necessary, for all time. On horizontal runs, iron hangers should be provided and the distance between these should not be more than 3 feet. Vertical stacks should be supported adequately, at least, every two stories.

Size of Soil and Waste Pipes. No soil pipe should be less than 4 inches in internal diameter, otherwise stoppages would be likely to occur; yet, on the other hand, these pipes should not be too large in diameter, as the flushing scouring action of the sewage passing through them would be lost, leaving them foul.

The size of the waste pipe is governed by the number of fixtures connected to it. A vertical waste pipe receiving the discharge from a kitchen sink or sinks should be 2 inches in diameter, and if receiving the waste from five or more floors it should be at least 3 inches in diameter and should have not less than 1½-inch branches. All bath wastes should be 1½ inches in diameter, while a 1¼-inch trap discharging into a 1½-inch waste will suffice for a lavatory basin.

The waste pipe from ice boxes or refrigerators should be 1½ inches in diameter for one or two floors, 2 inches for three and under five floors, and 2¼ inches for more than five floors. Each refrigerator must be trapped and must discharge with an open end into an open sink or into a deep-sealed trap. Where two or more

TABLE III

Weight per Lineal Foot for Wrought-Iron Pipe

Diameter (inches)	Weight (lb. per ft.)	Diameter (inches)	Weight (lb. per ft.)
1½	2.68	5	14.50
2	3.61	6	18.75
2½	5.74	7	23.27
3	7.54	8	28.18
3½	9.00	9	33.70
4	10.66	10	40.00
4½	12.49		

refrigerators are connected together, a vent pipe at least 2 inches in diameter must be carried up independently and must pass through the roof, Fig. 37.

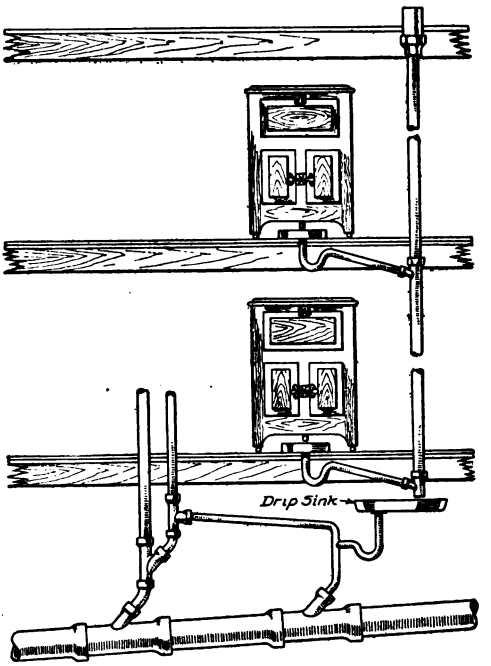


Fig. 37. Typical Waste-Pipe Layout for Refrigerators

Size of Vent Pipes. All water closets should be provided with vents 2 inches in diameter, and no main vent receiving the re-vent of one to three fixtures other than water closets shall be less than

TABLE IV

Sizes of Vent Pipes for Buildings of Various Heights

Stories	Size of Pipe (inches)	Fixtures Other than Water Closets	
		Stories	Size of Pipe (inches)
4 or under	2	4 or under	2
4 to 6	2½	4 to 8	2½
6 to 18	3	8 or more	4
18 or more	4		

1½ inches; for a greater number of fixtures, the vent must be at least 2 inches. Where an ejector for raising sewage is used, a 4-inch vent must be installed.

Table IV gives the size of vent required for water closets in buildings of various heights.

Where more than twelve closets are installed on any floor, the vent pipe should be at least 3 inches in diameter, with 2-inch re-vents connected to each fixture.

FIAT SYSTEM OF PLUMBING

Particularly Adapted to Big Work. A recently developed system of plumbing covering many excellent sanitary features, is the Fiat system, invented by Mr. G. Albin Nilson, a Chicago master plumber. Although comparatively new, its simplicity, practicability, and excellent sanitary characteristics have won for it the endorsement of many eminent engineers, architects, and sanitarians in this country.

The system has been tried out in many modern hotels and in office and large apartment buildings, for which it is specially adapted, but small installations give the same excellent results. The system is highly recommended by the sanitary department of the city of Chicago.

Advantages over Other Systems. A glance at a typical installation of the Fiat system, Figs. 38, 39, and 40, will show the essential characteristics of the system. It takes up less room than any other system and does away entirely with the somewhat bulky nickel-plated traps under the fixtures; all that is visible of the trap

and the waste connection is a bent piece of tubing extending only a few inches horizontally from the wall and a few inches vertically

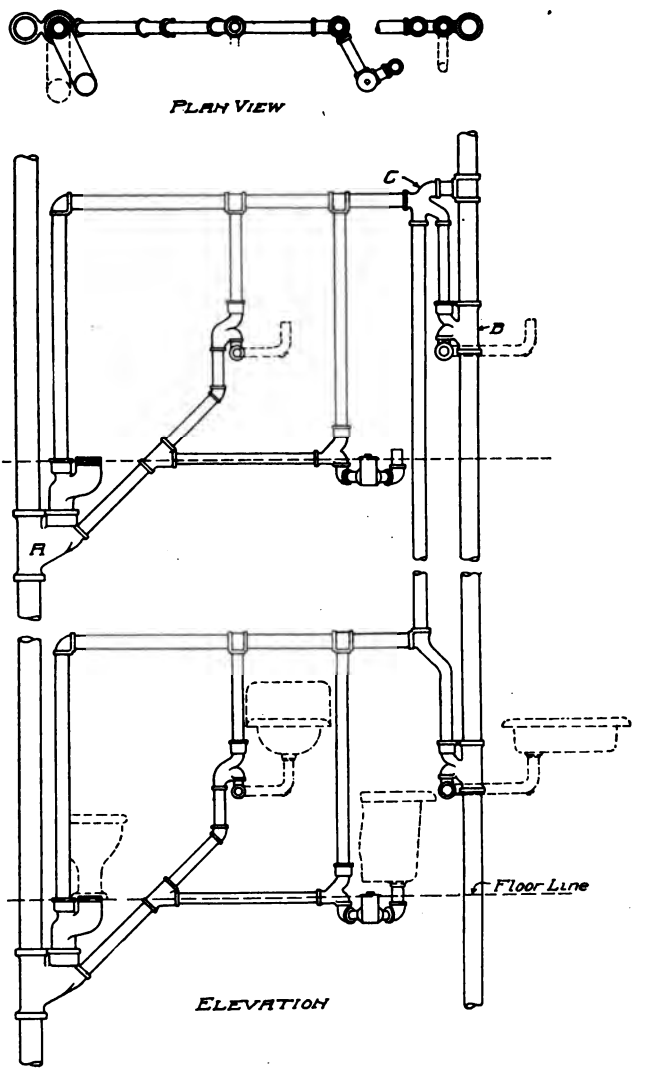


Fig. 38. Plan and Elevation of Fiat System of Plumbing

to the fixture. The bathtub waste is carried above the floor to the tub where the clean-out and trap are embedded only $4\frac{1}{2}$ inches in the concrete floor.

All running-screw connections and right-hand and left-hand threads are abolished and every fitting is made reversible and adjustable. This not only reduces the cost of the system considerably, but the elimination of the running-screw connections and the adoption of hub connections with calked lead joints gives a uniform strength to all re-vent lines besides adding to the flexibility of the system and allowing free expansion and contraction to take place, which is very essential in all high buildings.

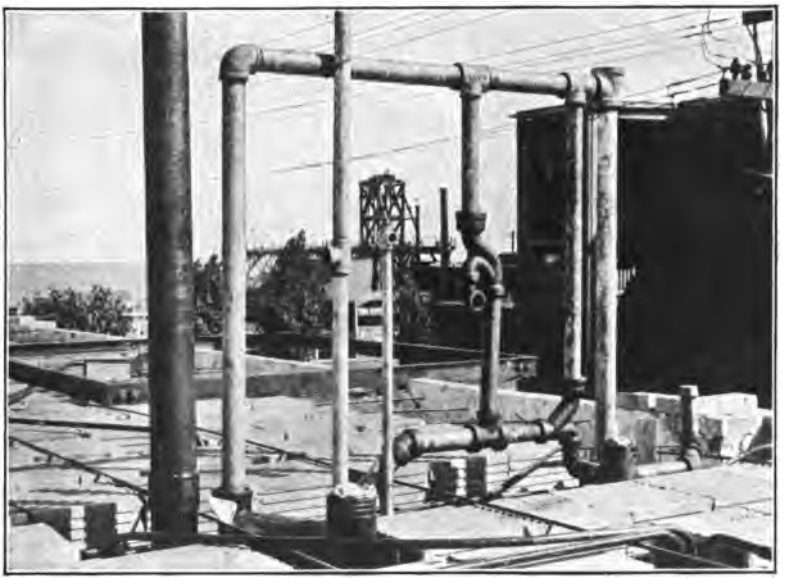


Fig. 39. Pipes of Fiat System in Place in Building under Construction

Avoiding Stoppage of Pipes. The general arrangement of piping, coupled with easy curves and angles in the fittings, obviates all danger of stoppages in any part of the system, and as the re-vent connections are vertical and continuous, vent stoppages through back flush cannot occur. Moreover, siphonage is impossible and an adequate circulation of air through the whole system is easily accomplished. All excremental matter from the closet enters the stack in a downward vertical direction, which renders a stoppage from a local fixture impossible; it is evident that anything which can pass through the closet bowl, when reaching the stack in a vertical downward direction, cannot choke the main stack.

Form of Closet Y. Another special feature of the system is the closet Y, shown at *A*, Fig. 38. This connection with the vertical stack is prepared for wrought-iron screwed pipe, while the opening receiving the closet head is a hub connection provided with a 2-inch hub to receive the re-vent pipe, directly over the center of the outlet, thereby making adjustable the upper end of the bend receiving the waste from the bowl.

No matter at what angle the closet bend is turned, it will neither interfere with nor change the location of the connection

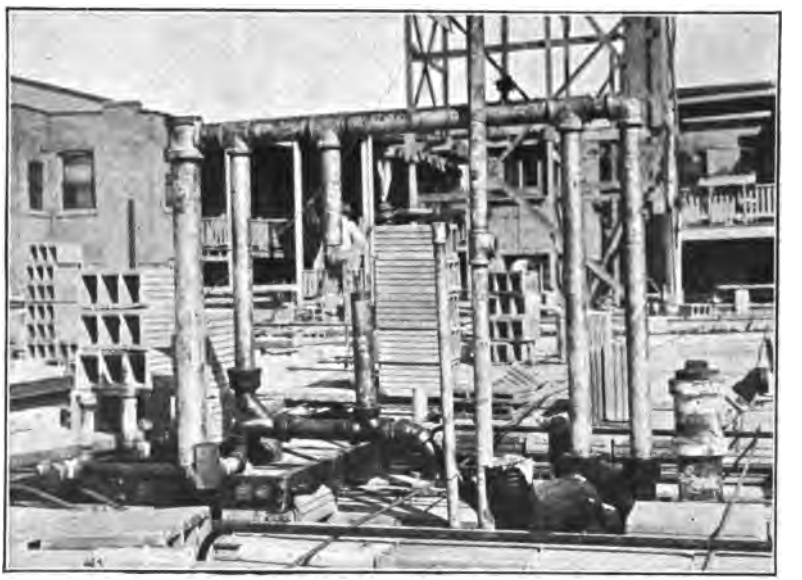


Fig. 40. Another Example of a Fiat Installation

for the re-vent. From this it will be seen that roughing-in measurements can be changed at will. Take as a specific example a closet bend 15 inches from the wall to the center of the inlet when at right angles to the wall. Assuming that a 12-inch instead of a 15-inch center is desired, simply move the stack either to the right or the left, then turn the closet bend to any angle giving the correct distance from the wall.

Lavatory Fitting. The lavatory fitting may be seen from Fig. 38 and from the section, Fig. 41. It is furnished with a screw connection to receive the waste line, while a hub is provided to

receive the re-vent, the joint being calked with lead which, as previously mentioned, adds flexibility to the system.

The connection between the lavatory and the fitting is as follows: A drainage street ell is screwed into the tapped opening and a nipple is screwed into the street ell which extends about $\frac{3}{4}$ inch outside the plastered wall. A nickel-plated tube is inserted into the nipple and a slip-joint connection is made. The upper end of the tube is connected to the lavatory basin with a similar slip joint. A clean-out plug is provided in the heel of the tube which permits the water to drain out when so desired and renders the whole accessible. However, it may be mentioned here

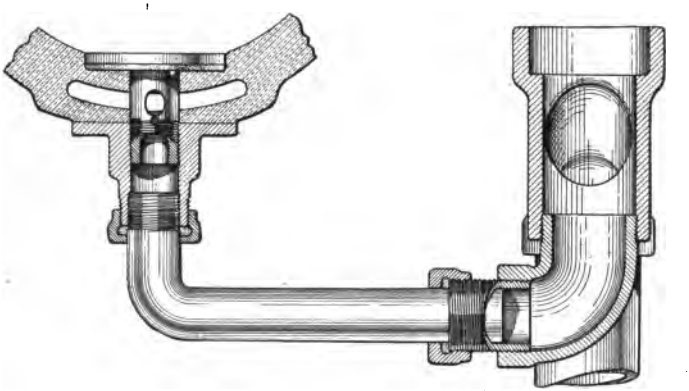


Fig. 41. Section of Fiat Lavatory Fitting

that with this form of water seal there is less likelihood of a stoppage occurring since, compared with the ordinary type of trap, there is only one-half as much bend to contend with. Further, there is a vertical down-flow after leaving the seal of the trap, and the short horizontal run between the lavatory and the fitting being constantly filled with water, foreign matter is afforded little opportunity to accumulate on the sides of the tubing.

One outstanding feature of this connection is that it can be turned to any angle to connect with the lavatory. It will be observed that the fitting is made in the shape of an offset which allows the lower end to be turned completely over to the right, thus gaining an adjustment of some 6 inches to meet the lower waste-pipe connection; this is executed without altering the center of the basin connection. Another ideal feature of the lavatory

connection is the small surface area between the basin itself and the water in the tube. This part, being alternately wet and dry, accumulates a certain amount of offensive matter which, when dry emits obnoxious gases into the room.

Bathtub Connections. The bathtub trap, clean-out, waste, and vent are shown in the section, Fig. 42, and also diagrammatically, Fig. 38. The horizontal waste line from the outlet of the fitting is installed above the rough floor which, as already explained, is of importance where concrete floors are used. The fitting has a screw-joint connection for the waste outlet, while the upper hub receives the re-vent; the joint being calked, the screw connection for the lavatory fitting is abolished. The lower end forming the waste inlet is a tapped screw-joint connection with the drainage street ell. A drum with an accessible and removable screw cover is installed on a level with the finished floor between the tub and the waste and trap fitting which forms the water seal. The drum, or cleanout, extends only $4\frac{1}{2}$ inches below the finished floor, which permits it to be installed in a 6-inch concrete floor slab without materially weakening it. Up to the time of introduction of the Fiat system, all concrete floors not exceeding 10 inches in depth had to be raised in the bathroom, or the ceiling had to be furred down to allow for this pipe space; even when this objectionable feature was overcome, the plumbing was inaccessible in case any stoppage occurred.

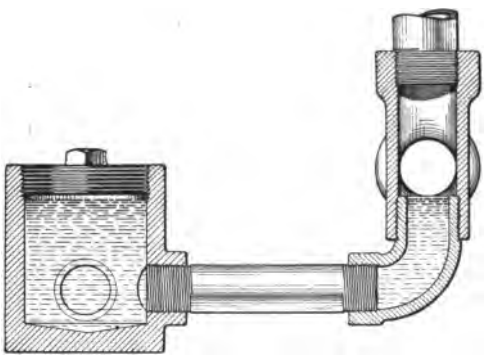


Fig. 42. Section of Fiat Bathtub Connection

Sink Waste Pipe. The sink waste pipe connections shown at *B*, Fig. 38, are almost identical with those of the lavatory, the only difference being in the fitting itself. Both the upper and the lower ends in the waste line are made with screw-joint connections, while the hub is connected to the re-vent pipe by means of a calked lead joint. The lower end, receiving the waste from the

sink, is a tapped-screw joint connecting with a street ell in exactly the same manner as the lavatory.

Re-Vent Fitting. A rather unique re-vent fitting in the top story is shown at *C*, Fig. 38. It is connected by means of a nipple into the main vent line of the waste stack, has four tappings to receive screw-pipe connections, and is so spaced as to make a vertical connection with the local vent from the sink and allow sufficient room for the vent line from the main stack.

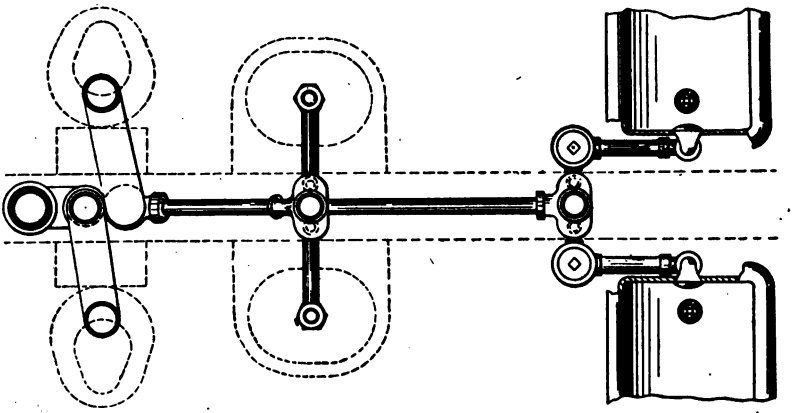
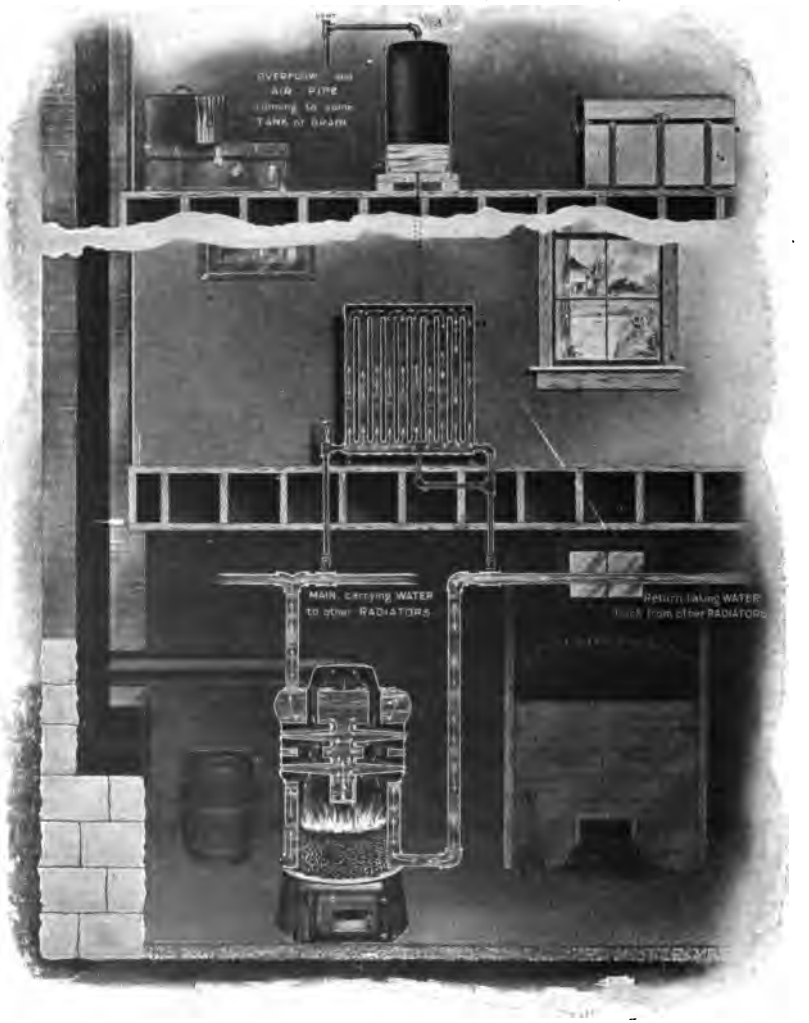


Fig. 43. Fiat Double Back-to-Back Fixtures for Large Apartment Building

This somewhat brief description will give a general idea of the Fiat system. The special fittings are made for wrought-iron screwed pipe, for extra heavy cast-iron pipe, and for all special purposes, as illustrated in Fig. 43, which shows double back-to-back fixtures installed in one of Chicago's large apartment buildings. It will be observed that in this instance the usual partition divides the toilets and that special fittings meet the requirements of the two closets and the vents from them.



PRINCIPLE OF HOT-WATER HEATING ILLUSTRATED BY TRANSVERSE SECTIONAL VIEW, SHOWING BOILER, RADIATOR, AND EXPANSION TANK

Courtesy of American Radiator Company, Chicago

DOMESTIC HOT-WATER SUPPLY

HEAT TRANSMISSION

Importance of Laws of Heat. Before one can sucessfully devise or install any hot-water apparatus he must make himself thoroughly conversant with the physical laws pertaining to the subject. The writer has had to answer a thousand or more queries on the causes of failure of hot-water apparatus and, although a great variety of questions would be expected, yet the failure of every plant was due to the lack of knowledge of the physical laws governing the work or of the proper proportion between the heater, boiler, etc.

Let us, then, briefly consider some of the most important properties of heat. Heat may be transmitted by three distinct methods: conduction, radiation, and convection.

Conduction. Heat is transmitted by conduction from particle to particle in a substance. If a fire is lighted under a copper heater, the heat is transmitted through the particles of metal until the interior becomes quite hot, thus heating the water. Most metals are good conductors of heat while non-metals, liquids, and gases are poor conductors. Water will not conduct heat in a downward direction and this is the reason why all circulation pipes must have a pitch in an upward direction and be free from all sags, traps, etc.

Radiation. When heat is radiated, it is given out in straight lines in every direction from some source. It does not heat the air through which it passes nor is any heat experienced until the rays impinge upon a solid body. A typical example is the radiant heat given out by the sun. We rely partially upon radiant heat to warm our buildings by means of radiators filled with hot water or steam, but in a domestic hot-water supply the circulation pipes also are throwing out radiant heat, thus wasting valuable heat and oftentimes warming some portion of the building we desire to keep cool. From this we learn that long lengths of circulation pipes

waste heat and the boiler must be placed as close to the heater as practicable. If for any reason it is not convenient to have these side by side and, therefore, long lengths of piping are unavoidable, such pipes should be covered with a nonconducting material which will prevent 90 per cent of the loss by radiant heat.

Convection. All water is heated by convection currents and if no convection and gravitation existed it would be totally impossible to obtain hot water. Convection may be described as the act of conveying heat by the ascent of heated particles. The fire is lighted under the heater and the molecules of water nearest the heater, receiving heat first, expand and become lighter than the cold and heavier water in the boiler. The heavy cold water falls by its superior weight and forces the hot and lighter molecules up to the highest part of the boiler, thus keeping up a continuous circulatory movement as long as a fire is kept going.

Expansion. The expansion of water when heated must be closely considered when devising hot-water apparatus. Water expands $\frac{1}{25}$ of its own bulk when heated from a freezing point to a boiling point, so that an apparatus containing 100 gallons of water before the fire is lighted under the heater will require provision for 104 gallons. Anything that expands becomes lighter, bulk for bulk than the original matter, and for this reason hot water always finds the highest point. Expansion of water is taking place in every system and with the tank or gravity method a pipe must be carried well above the storage tank supplying cold water to the system to allow the expansion overflow to discharge into the tank. In the street-pressure system no expansion is necessary, for as the hot water increases in bulk, it forces the cold water supply back into the street mains. A check valve should never be placed on the cold water supply, unless adequate provision can be made by providing a suitable pipe capable of holding the expanded water. If this detail is not complied with, the apparatus will give way at the weakest point.

CHARACTER OF WATER

Hard and Soft Waters. Consider, now, the character of water as supplied in various districts. All water is derived from the rainfall, and the kind of water finally obtained depends upon the

character of the ground it falls upon. Water is either soft or hard, the latter being again divided into *temporary hard* and *permanently hard.*

Soft water. If the rain, which is distilled and soft water, falls on granite, hard volcanic rocks, steep hillsides, peat, heather, moorland, or cultivated land, it remains soft and invariably has a very solvent action on iron, zinc, and lead—so much so, that the supply derived from many sources will corrode or rust a wrought heater, constructed of $\frac{3}{8}$-inch plates, completely through in a period varying from three months to three years. Besides this grave nuisance, the water is so brown in color and contains so much iron in suspension that it is unfit for even washing household utensils. Galvanizing is very little protection, for the soft water readily attacks zinc and leaves a surface of the iron exposed to the action of the water. Lead-lined tanks should never be used with soft water, for should the water become warm it acts more readily on lead, dissolves a portion, and carries it in solution. If this water be consumed by the inhabitants of the dwelling they doubtless will suffer from lead poisoning. The only satisfactory material to use in a soft water district is copper—copper heater, copper boiler, and copper pipes—while the cold-water storage tank may be constructed of copper, slate, or porcelain. Soft water has no action on these materials. Iron heaters, boilers, tanks, and pipes can be made red hot and then exposed to a current of steam for several hours. This process is supposed to render them perfectly impervious to the action of soft water. If skillfully executed, the process is satisfactory, but there is always the danger of leaving a small surface unprotected which will be attacked by the water. Again, this is rather an expensive process and makes the cost of iron almost as much as that of copper. Where the initial cost has to be considered, iron pipes lined internally with copper can be used. This form of pipe possesses the advantages of both iron and copper and is capable of withstanding a great pressure.

Hard Water. Hard waters are due to the rain falling on lime, chalk, and red sandstone. *Permanently hard waters* contain calcium sulphate and magnesium sulphate which has practically no action on any material that may be used in connection with a hot-water apparatus and any of the following materials may be used:

For heaters, cast iron, wrought iron, copper; for boilers, plain iron, galvanized iron, copper; for cold-storage tanks, plain iron, galvanized iron, copper, slate, porcelain. Of course, for a water of this description, galvanized iron is adopted most extensively on account of its lightness and cheapness. Lead pipes can be used with this water and have the advantage of being easily bent in any direction and a connection can be taken out wherever one is desired.

Temporary hard water contains the carbonates of lime and gives rise to all the trouble occurring through the furring—incrusted deposit or lime deposit—in heaters and circulation pipes. The process is as follows: The rain absorbs the carbon dioxide gas from the air as it falls from the clouds and also as it percolates into the ground (the ground contains 250 times more of this gas than the air above it). This water charged with carbon dioxide dissolves a small quantity of lime and carries it in solution. On reaching the heater, the heat from the fire causes the water to become very hot at times, and this water being under pressure often attains a temperature of 300° F. When the water reaches these high temperatures the carbon dioxide is driven off, thus immediately liberating the lime and precipitating it on the sides and bottom of the heater and in the circulation pipes. It must be remembered that a considerable quantity of fresh water has to pass through the heater each day and each heater full of water deposits a quantity of lime. The exact quantity depends on the hardness of the water and the temperature it reaches in the heater. No lime is precipitated unless a temperature of 212° F. is reached. This deposit must be cleaned out at regular intervals by removing the circulation pipes and heating and hammering them on a solid body until all the deposit is shaken out. The contents of the heater may be chipped out with a hammer and chisel. In all cases the circulation pipes should be at least $1\frac{1}{4}$ inches in diameter, then it will take longer for them to stop up; when stoppage actually occurs, the lime will be more readily removed than in the case of a 1-inch or $\frac{3}{4}$-inch pipe. If the deposit is allowed to accumulate, the heater and pipes become partly choked and give rise to a very disagreeable noise. Moreover, a little hot water can be obtained, for the lime, being a bad conductor of heat, prevents the

heat passing through to the water. The heater is also liable to be fractured, for the lime prevents the water from coming into contact with the surface of the heater. One often hears the expression: "Copper heaters and circulation pipes should be used in temporary hard water districts, for the lime deposit will not adhere to copper". Now this opinion is incorrect, for it has already been shown that water causes the trouble and not the material. Moreover, if copper is used, being of a soft nature, it is more likely to be damaged with the hammer and chisel than iron. On no account should lead pipes be used, as the incrusted deposit cannot be removed and consequently the pipes will have to be thrown on the scrap heap. Any material can be used for boilers, tanks, and supply pipes, for the water in the boiler rarely becomes hot enough to liberate the lime. Furthermore, if such a temperature is reached all the lime in the water is sure to be liberated in the heater.

HEATERS AND BOILERS

Size of Heater. The heater itself must receive special attention. As already mentioned all hot water is derived from the heater and, if we wish to obtain successful results, we must use discretion in selecting an efficient type for the varying conditions under which they may operate. One type may give excellent results with one particular heating system yet prove totally unfit for another. The capacity of the heater is regulated by the demand for hot water in any building. Many persons are under the impression that the smaller the heater the quicker the circulation; consequently, an abundant quantity of hot water will be obtainable in a short time. Others argue that the heater should be as large as possible, for all the water comes from it. Now, in the first instance, let us assume that we have a heater of 1-gallon capacity and a 250-gallon storage capacity for the hot water in the storage tank, known as the boiler. The circulation under these conditions will be quick, but such a small volume of water passes into the boiler that it will be very late in the day before an appreciable quantity of really hot water can be drawn from the faucets. Coming now to the second argument, that is, a large heater, an apparatus which recently came under the writers' notice consisted

of a 48-gallon heater while the boiler contained only 30 gallons. This apparatus is quite as bad as the first for no ordinary range has sufficient fire area to heat such a volume of water, and an independent type would be necessary which, in this case, would keep the 30 gallons boiling all the time. The required grate surface of the heater may be computed as follows: First determine or assume the number of gallons to be heated per hour and the required rise in temperature. Reduce gallons to pounds by multiplying by 8.3, and multiply the result by the rise in temperature to obtain the number of thermal units. Assuming a combustion of five pounds of coal per square foot of grate and an efficiency of 8000 thermal units per pound of coal, we have the formula

$$\text{grate surface in sq. ft.} = \frac{\text{gallons per hour} \times 8.3 \times \text{rise in temperature}}{5 \times 8000}$$

Example. How many square feet of grate surface will be required to raise the temperature of 200 gallons of water per hour from 40 degrees to 180 degrees? Substituting values in the above formula, we have

$$\text{grate area} = \frac{200 \times 8.3 \times (180 - 40)}{5 \times 8000} = 5.8 \text{ square feet}$$

In computing the amount of water required for bathtubs, it is customary to allow from 20 to 30 gallons per tub, and to consider that the tub may be used three or four times per hour as a maximum during the morning. This will vary a good deal, depending upon the character of the building. The above figures are based on the apartment hotel practice. For all buildings other than cottages, the independent heater is preferable to the range water back, but many think otherwise. The popular arguments against its use are as follows: A fire has to be kept going in the kitchen range for cooking purposes, etc., and a water back might just as well utilize the waste heat; moreover, the independent type takes up time attending to it and it burns a quantity of fuel.

Now it is true that the water back does utilize a small quantity of heat, but it is very extravagant and takes up nearly all the heat from the fire. The cold heater deadens the fire and requires a quicker draft to keep it sufficiently bright than when fire bricks exist instead of the heater. Thus, without the heater

the range would require less attention, less fuel, and work much better. The independent heater will burn coke, cinders, or any household garbage, thus acting as a small incinerator. It requires only five minutes attention twice a day and will supply an abundant quantity of really hot water any time, day or night. Hot baths can be had without the least inconvenience before breakfast, which is beyond the capabilities of most range heaters. In temporary hard-water districts, the heater can be cleansed without interfering with the cooking processes. It stands complete in itself and can be put down in any position, while the chimney can be independent or connected with any existing flue. In hard-water districts, the heater should be provided with a waterway bottom, into which the lime falls in the form of a sludge and remains in this state until removed from the mudhole provided at the bottom.

Boilers. It is essential in most systems to provide some means of storing the hot water, for the heater is of small capacity and, therefore, the hot water is quickly exhausted. A boiler properly proportioned to the size and power of the heater and amply large enough to meet the demands for hot water at the busiest time of the day is imperative to store the hot water derived from the heater. The material used has already been described, but whatever the material, it must be capable of withstanding a pressure of 40 pounds per square inch and should in every instance be tested before leaving the works. As a general rule, the boiler is sent out with two openings for the pipe connections on the top, two on the side and one at the bottom, but these can be placed in any desired position if specially ordered.

SYSTEMS OF SUPPLY

Street Pressure System. A street pressure system suitable for the ordinary type of small residence is shown in Fig. 1. A pipe is taken direct from the street pressure supply and connected with the top of the boiler. A tube is carried down to within 6 inches of the bottom to prevent the cold water from discharging and splashing into the hot water which, naturally, is at the top of the boiler. The tube should have a $\frac{1}{8}$-inch hole drilled in about 1 inch from the top of the boiler so that air will enter and break

the siphon and thus avoid inadvertently emptying the boiler when intending only to cut off the supply and drain the pipe. The siphon-hole, as it is termed, should be turned in the direction opposite the eccentric hole, which is for the hot-water exit, so that the stream of cold water which issues there when water is coming into the reservoir will not cut across and interfere with the hot service which is always leaving the boiler at the same time. If the delivery were placed nearest the side hole, hot water from the stove would have to pass around it in order to reach the exit. Delivering the cold water through a pipe passing down through the volume of hot water is no material retardation of the heating process. The heat thus absorbed by the cold delivery is simply that much aid to the ultimate purpose. This cannot be said of the siphon-hole jet when directed across the hot exit or in its direction. The object in putting the siphon-hole near the upper head is to avoid siphoning more water than necessary, as the waste tubes of the stop and waste cocks are generally left open, not connected to drains, and often not even discharging where the waste can be left to take care of itself. Moreover, it is a waste of the stored hot water to siphon out several inches from the hottest point. The cold water now passes into the heater through the pipe provided at the bottom of the boiler, receives heat, convection currents are set up, and the hot water circulates back into the boiler through the hot flow pipe furnished about 18 inches from the bottom of it. Care should be taken not to have the hot flow pipe connected below the extreme top of the heater, otherwise an air space or air pocket which cannot be filled with water will be formed, thus causing the formation of steam

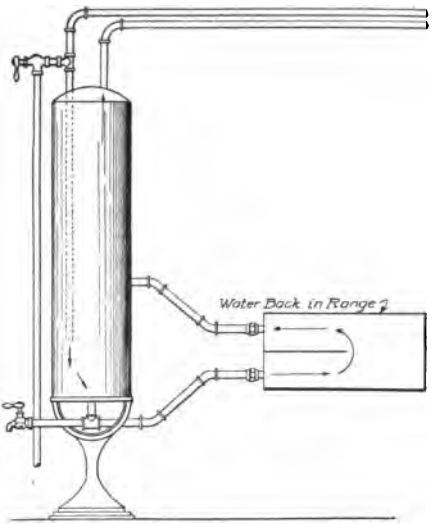


Fig. 1. Diagram of Street Pressure Water System for Small Residence

with accompanying noises, even if no other consequence presents itself.

A pipe is taken directly off the top of the boiler and is carried to the various points at which a supply of water is desired. The street pressure brought to bear on the contents of the boiler forces the water to the desired height and, assuming the fire is kept going and the aforementioned details are complied with, hot water will be obtainable on the opening of a faucet. A sediment cock should be provided on the cold supply to the boiler, so that the entire contents of the system can be emptied in the case of repairs, etc. Further, all sediment occurring in the boiler can be removed periodically through this cock. It is very convenient to fix a shut-off cock on the cold supply close to the boiler. This cock when closed shuts off the whole of the hot water supply, yet it does not interfere with the cold-water supply throughout the building.

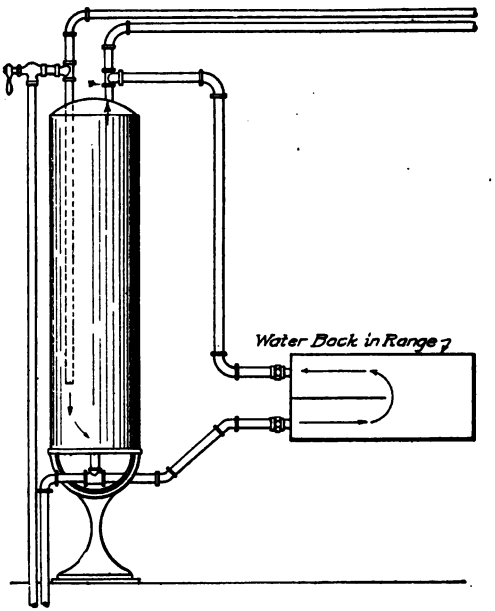


Fig. 2. Modification of System Shown in Fig. 1, Giving Quicker Results

Where quick results are desired, the flow pipe is not taken to the boiler as shown in the former method but connects with the hot supply some 6 inches above the top of the boiler as shown in Fig. 2.

Disadvantages of System. Theoretically, the system is ideal, for it is not necessary to heat the entire contents of the boiler before hot water is obtainable. As soon as the fire is lighted the hot water circulates direct into the supply pipe and can be drawn from the faucet without delay. However, in practice the results are not all that could be desired. It must be remembered that as soon as a faucet is opened, all circulation ceases and the water

flows from every direction to the point of issue. Thus, the cold water rushes through the heater direct to the faucet, and the fire under the heater is not capable of raising the water to a satisfactory temperature in such a brief space of time. It is serviceable when about one gallon of water is required.

Secondary Circulation System. The connection for a secondary circulation is shown in Fig. 3. If the building is such that it necessitates long straggling branches, the hot-water supply pipe must be carried from the top of the boiler, with a pitch of at least $\frac{1}{4}$ inch to one foot, to the remotest branch, thence returning to the cold supply to the heater with a continuous fall. It must be clearly understood that there is no circulation in a single pipe and, if long branches are in vogue, the whole contents of the branch pipes will have to be run off before hot water is forthcoming. Just as soon as the faucet is closed the hot water contained in the branch pipe becomes stagnant and cold. To obviate this the circulation pipe, or secondary flow and return, as already described, is adopted, which allows the water to circulate continuously throughout the entire system. The branches to the fixtures which must be as short as possible, can be taken from the flow, that is, the pipe rising to the highest point, or the return, the pipe returning to the cold supply to the boiler. Sometimes provision is made in the boiler for the connection, 4 to 8 inches from the top. This is really the correct position and will give the most satisfactory results; manufacturers do not, as a rule, provide this connection on their stock boilers.

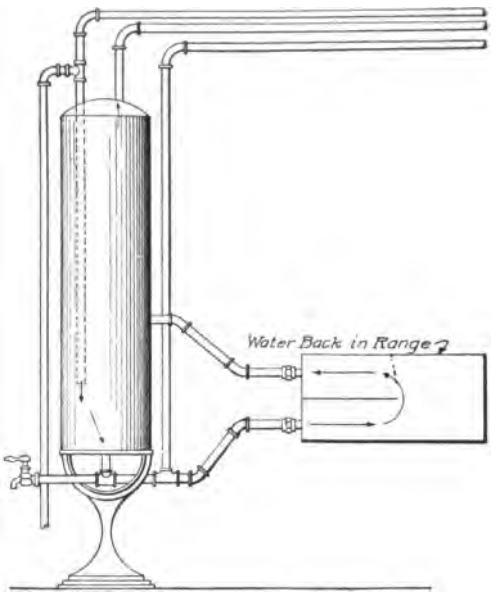


Fig. 3. Diagram of Hot-Water System with Secondary Circulation

Gravity Supply System. A typical arrangement of the gravity supply system is shown in Fig. 4. This method of domestic hot-water supply constitutes an entirely different arrangement of supply, services, etc., to those previously mentioned. The outflow of hot water through the faucets depends on the pressure derived from the cold-water storage tank which, naturally, must be fixed in an elevated position above all the fixtures to be supplied. This tank is supplied with water direct from the street main, if the height of same renders such a procedure practicable, or in case of high buildings where the street pressure is not capable of raising the water to the desired height, a pump, water lift, or other mechanical device is employed. The tank must be provided with an overflow pipe sufficiently large to carry off any surplus water and discharge with an open end into an open water-supplied sink or into a deep-sealed trap. The boiler, the heater, and cold supplies to the faucets are supplied direct from this tank, and to take care of the expanded water an expansion pipe is taken off the highest point of the apparatus, carried up two feet above the top of the tank, and discharges with an open end into the latter. Branches are taken out of the hot-supply pipe and, if so desired, a secondary circulation may be used in connection with the system. It is absolutely imperative to adopt this method in those districts having an indirect water supply, where the water is only turned into the mains a few hours daily, also in high buildings as the street pressure in most localities will not raise the water to a greater height than five stories.

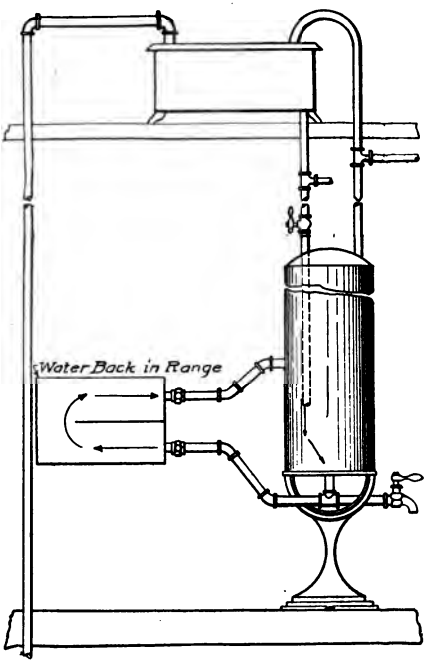


Fig. 4. Diagram of Gravity-Supply Hot-Water System

Double-Boiler System. *Method A.* The double boiler, Fig. 5, is adopted when the pressure of the water in the street mains will not supply the upper floors of the building with water and it is not desired to supply the entire building from a tank. The lower floors of the building are supplied with the street pressure supply and the upper ones from a tank on the gravity system. One heater in the range, or preferably an independent heater, heats the water of both supplies by means of a double boiler. This consists

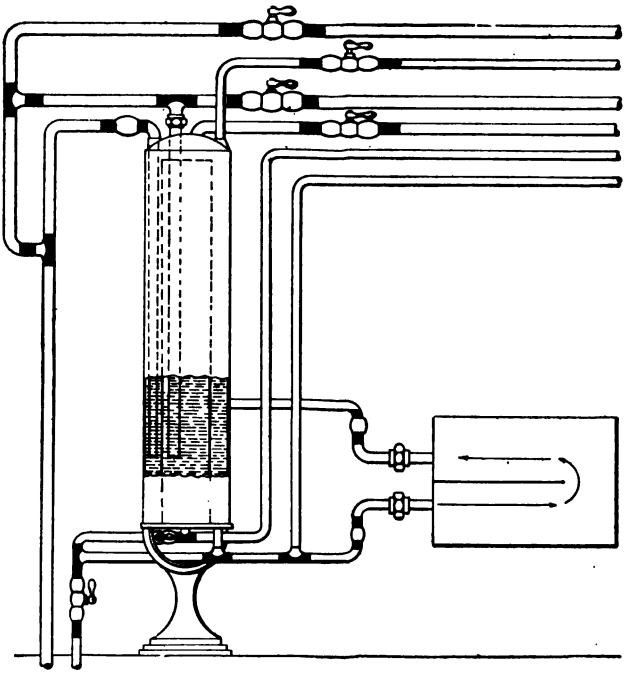


Fig. 5. Diagram of Double-Boiler System of Hot Water, Both Street Pressure and Gravity Tank Being Used

of a boiler within a boiler. The inner boiler contains the water from the tank and is known as the *high-pressure* boiler, while the other is supplied direct from the street pressure and is termed the *low-pressure* boiler. The water in the outer boiler is connected to the heater and the water in the inner boiler is heated by conduction through the boiler shell. A by-pass is provided between the two cold supplies to the boilers and controlled by a check valve. The draw-off cocks of the boilers are arranged in such a manner

that the water in the inner boiler cannot be drawn off without emptying the outer boiler at the same time, so that in the event of failure from the tank supply, the street pressure supply would keep the inner boiler supplied through the check valve and prevent it from collapsing. If the water be drawn from the inner boiler and the outer boiler is kept full, the excess pressure of the outer boiler would collapse the inner one. It may be mentioned here that the double-boiler practice is rapidly losing favor owing to its general inefficiency. The inner boiler being heated by conduction, it is imperative to use copper plates of light weight in its construction, and these invariably give way under the expansion, contraction, and pressure of the water, causing the water from the two to intermingle and make one boiler instead of two.

Method B. Another method of providing double-boiler service is shown in Fig. 6. *A* is a $1\frac{1}{4}$-inch pipe leading directly to the tank and bending over the top. It is connected to a pump

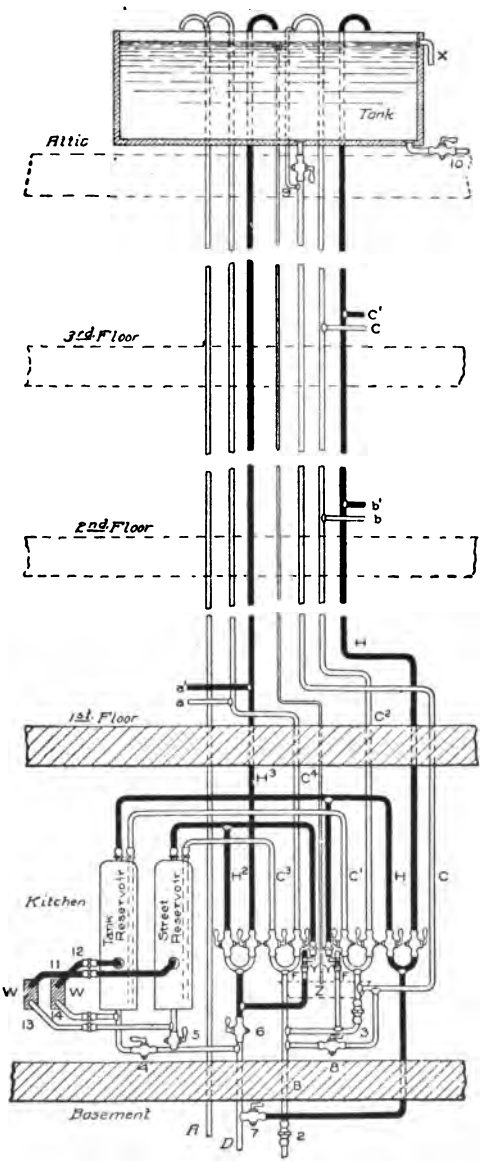


Fig. 6. Layout for Another Double-Boiler System

in the basement. *B* is the main supply from the street to which pipe *A* is connected at a lower point; *2* is a check valve placed in the main street supply for the purpose of preventing the pump from drawing water from the street pressure boiler while pumping water into the tank in the attic. This might occur for various reasons if a check valve is not used, and would certainly result in case the pump should be operated while the street supply was shut off. Check valve *2* also prevents the tank water from going into the street pipe when both systems are working at high pressure. In practice, a drain cock should be placed in pipe *B* above check valve *2*. *C* is the main cold supply leading directly from the tank to the kitchen without branches to fixtures at any point. It connects above check valve *3* to a pipe leading to the tank pressure reservoir. From the lower end of check valve *3*, a pipe leads over to the main cold supply *B*. The superior pressure of the tank system keeps check valve *3* closed, so that water cannot enter the tank system or reservoir from the street while there is pressure upon it from the tank supply. However, immediately upon the tank becoming empty, or its pressure shut off at cock *9*, the pressure falls in the tank system pipes until the pressure is inferior to the street pressure, and check valve *3* opens upward and allows the street pressure to keep the tank pressure reservoir filled. Otherwise, trouble might possibly result, but it is not so probable as in jobs having one boiler within the other. This check admits of both boilers filling without having water in the tank when the job is first started; and, although it is a minor point to mention, it is best to be prepared for accidents.

The main cold supply from the tank is controlled by stop cock *9*. Just below the cock a small pipe is branched in, carried up, and curved over the top of the tank so as to admit air when it is desired to drain the pipe. *D* acts as a drain to the hot water pipes of both boilers. The sediment pipes of the boilers are also connected to it.

To aid the reader in tracing the different pipes easily, all the hot-water pipes are represented by heavy black lines and the cold water pipes by double parallel lines. *C'* is the cold supply to the tank pressure reservoir; C^2, tank supply, cold water, to fixtures on second and third floors; C^3, cold supply to the street pressure

reservoir; and C^4, cold supply from the street pressure to the fixtures on the first floor. *FF* are the hot and cold-water faucets at the kitchen sink, the hot being on the left side. *H* is the main hot supply of the tank system; *H'* is the hot supply from the tank reservoir to the fixtures on the second and third floors; and H^2 is the main hot supply from the street pressure reservoir to the fixtures on the first floor. It will be noticed that each of the supplies has been carried up as high as the top of the tank and curved at the end so that they will discharge into it, which, in the case of hot supplies, might occur from steaming. The extension of the fixture supplies to the top of the tank, with the ends left open, insures that they will drain themselves when the water is shut off; and also cushions the pressure when the faucets are turned off quickly, the same as the air chambers do on direct-pressure systems.

The hot and cold supplies from the street reservoir might be left off at any point where the branches are made on the first floor, without causing any material difference in the working. In that case, however, there would be no vapor relief for the reservoir through the hot-water pipe; and when the cocks were shut off, none of the pipe would drain unless the faucets were opened upstairs. As it is, the main line will drain whether the faucets are open or not; and there is also the advantage of the air cushion and relief as well.

Of the cocks over the kitchen sink, only those which have waste tubes indicated on the pipes leading to the fixtures on the upper floors, are stop and waste cocks. The others are plain stops which prevent any chance of causing them to waste continually by some error in using them. Stops and wastes would be of little value on the lines above the sink which lead direct to the boilers, because it is not particularly desirable to drain any of the pipe between the cocks and the reservoirs while the cocks mentioned are shut off.

The branches *aa'*, *bb'*, and *cc'* are of $\frac{5}{8}$-inch pipe and supply pipe and supply fixtures on the first floor from the street pressure and on the second and third floors from the tank pressure. *WW* represent water backs, both of which are in the same range of firebox. One water back is connected to the tank reservoir by

means of circulating pipes *12* and *14*, while the other is connected to the street reservoir by pipes *11* and *13*. The sediment pipes of the reservoirs are controlled by cocks *4* and *5*. Both of the sediment pipes discharge into the general drain pipe *D*. The overflow pipe of the tank is indicated by *X*. *Y Y* are vacuum valves situated over the kitchen sink. They communicate with the reservoirs through branches from the main hot supplies.

By referring to the engraving the reader will see that there is no way to cut off communication between the reservoirs and the vacuum valves. With the valves placed at the sink as shown, the weight of the water in the vertical pipe above the valves must be overcome before air will enter the reservoirs. If desired, the valves may be placed in the heads of the reservoirs, and a pipe carried over to the sink to take care of the drippings. In this style of double-boiler work, vacuum valves are not so important as they are in systems having one reservoir within the other, because the boilers here described work under about the same conditions as those in ordinary single-boiler jobs. The telltale pipe *Z* discharges over the kitchen sink. Cock *6* drains the hot-water pipe from the street reservoir and cock *7* drains the hot-water pipe from the tank reservoir.

Cock *8* is placed in a connection where, when turned on, it allows the tank pressure to by-pass check valve *3*. By this means both systems may be worked under high-pressure duty when the street pressure is shut off. In a case where the street pressure is constant for the fixtures on the first floor, but does not reach the second, cock *8* will seldom have to be used, and it should then be of a type having a removable handle.

One point gained by bringing the pipes down and up, as shown by the loops over the sink, is that every stop can be reached from the floor without the aid of a ladder. The fixtures on the upper floors can be shut off without interfering with the supply to the kitchen sink or other fixtures that may happen to be on the lower floors.

The sizes of the pipes shown in this installation, which have not already been given, are as follows: *B* and *C*, $\frac{3}{4}$ inch; *C'*, *C*^{2}, *C*^{3}, and *C*^{4}, $\frac{5}{8}$ inch; *D*, $\frac{3}{4}$ inch; *FF*, $\frac{5}{8}$ inch; *H*, *H'*, *H*^{2}, and *H*^{3}, $\frac{5}{8}$ inch; *X*, $1\frac{1}{2}$ inch; *YY*, $\frac{1}{2}$ inch; Z, $\frac{3}{8}$ inch; *11* and *12*, 1 inch;

and *13* and *14*, $\frac{3}{4}$ inch. Cocks *4* and *5* are $\frac{3}{4}$ inch; *6*, *7*, and *8*, $\frac{5}{8}$ inch; and *10*, $1\frac{1}{4}$ inch.

Horizontal Boilers. A horizontal boiler connected to an independent gas heater is shown in Fig. 7. Where space is limited, such as in the basement of a building, it is often difficult to install a vertical boiler of adequate size to store the necessary amount of hot water. However, this difficulty is easily overcome by suspend-

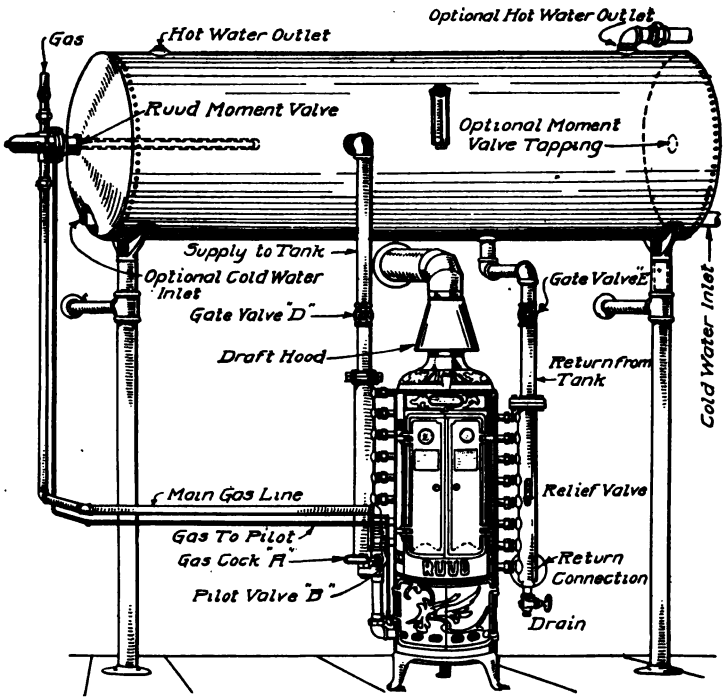


Fig. 7. Complete Layout for Hot-Water Storage System, Using Ruud Automatic Gas Heater

ing the boiler by means of strong iron hangers from the basement ceiling in a horizontal position and immediately over the heater. The connections are very similar to those adopted in the other system. The supply may be direct from the street or, in the case of high buildings, from the tank in the attic. The boiler tube with the siphon-hole is carried down to within 3 inches from the bottom of the boiler and the cold water flows through the cold

supply to the heater fixed in the bottom or in the side 3 or 4 inches from the bottom. The hot circulation pipe is connected in one end and about the center of the boiler, while the hot supply

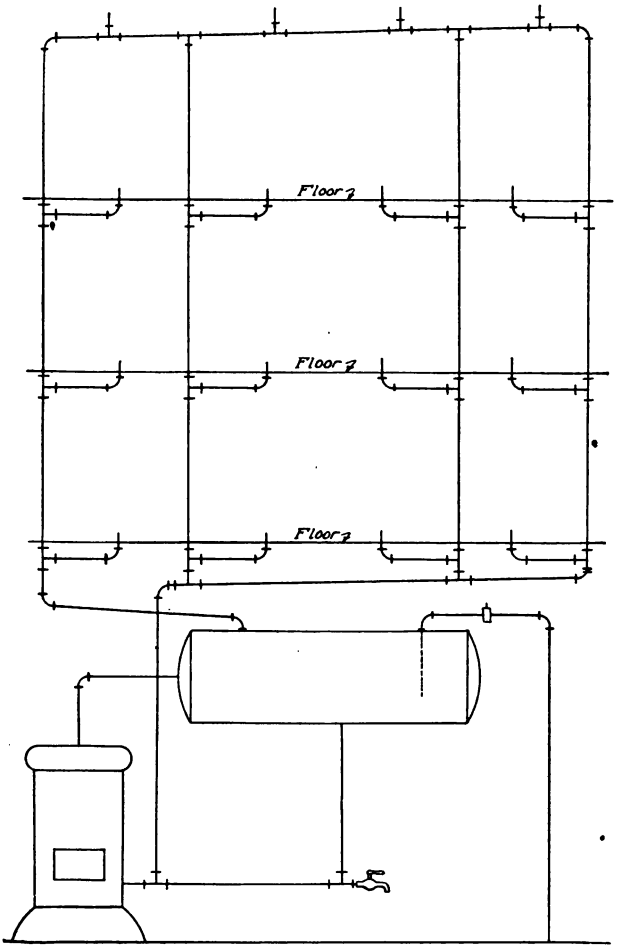


Fig. 8. Layout of Hot-Water System with Horizontal Boiler for Large Building

is taken off the extreme top and supplies the fixtures. An emptying pipe with sediment cock must be provided for emptying and cleansing purposes.

Another horizontal boiler arrangement suitable for a fairly large building is shown in Fig. 8. The horizontal boiler is supplied

direct from the street pressure and the hot water is derived from an efficient independent heater. The secondary circulation pipes rise to the highest point, thence returning to the cold supply to the heater. It will be noticed that branches are taken from both the flow and return pipes.

The ordinary vertical boiler may be used as a horizontal boiler without making any alteration. Most vertical boilers have two openings on the top—one for the hot supply to the fixtures and the other for the cold supply to the boiler. When this boiler is fixed in a horizontal position with the side connection facing the ceiling, both the flow and the return from the heater

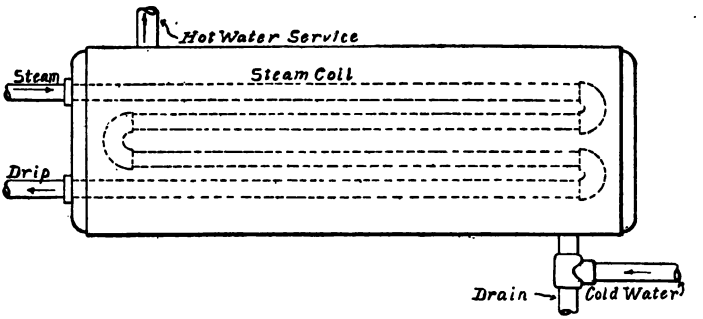


Fig. 9. Horizontal Hot-Water Storage Reservoir with Steam Coil of Brass Pipe for Heating Used Where Steam Pressure Is Constantly Maintained

are connected with these openings. The cold supply is connected with what would ordinarily be the return to the heater, a 45-degree ell and a short piece of pipe being attached in order to convey the cold water to the bottom of the boiler. The flow pipe from the heater is connected with the hot supply about 4 inches from the top of the boiler, while the return to the heater is taken from the center of the boiler and usually forms the hot supply to the fixtures. A 45-degree ell and a short piece of pipe are carried to within 2 inches of the bottom of the boiler.

Steam Coils. In apartment or other houses where steam pressure is constantly maintained, the whole plumbing system is usually supplied with hot water through the medium of a reservoir provided with a steam coil of iron, brass, or copper pipe, as shown in Figs. 9 and 10. The *trombone*

coil, illustrated in Fig. 9, can be used only on horizontal tanks; it would not drain in any other position. The condensed steam is wasted into the sewer, delivered to a hot well, or returned by steam trap.

The efficiency of a steam coil when surrounded by water is much greater than when placed in the air. An iron pipe will give off about 200 thermal units per square foot of surface per hour for each degree difference in temperature between the steam and the surrounding water. This is assuming that the water is circulating through the heater so that it moves over the coil at a moderate velocity. The condensing power of galvanized pipe is very nearly the same as that of plain iron, its coating being an alloy and not pure zinc as is generally supposed. The ratio of absorption decreases as the temperature of the water approaches that of the steam surface. In assuming the temperature of the water, take the average between that at the inlet and that at the outlet.

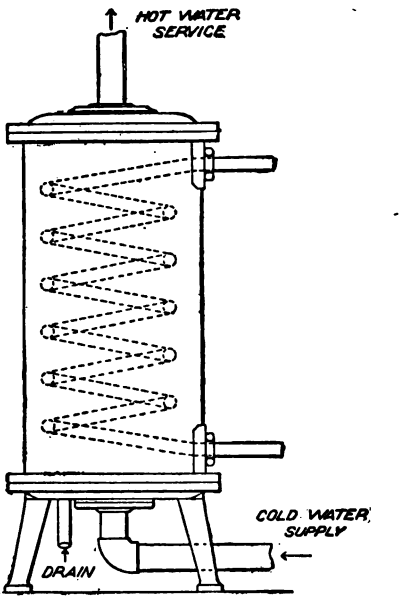


Fig. 10. Vertical Storage Reservoir with Steam Coil of Iron, Brass, or Copper Pipe for Heating, Used Where Steam Pressure is Constantly Maintained.

Example. Find the heating surface required in an iron coil to heat 100 gallons of water per hour from 38 degrees to 190 degrees, with steam at 5 pounds' pressure?

Water to be heated = $100 \times 8.3 = 830$ pounds.

Rise in temperature = $190 - 38 = 152$ degrees.

Average temperature of water in contact with the coils

$$= \frac{190 + 38}{2} = 114 \text{ degrees.}$$

Temperature of steam at 5 pounds' pressure = 228° approximately (actually 227.964°).

The required B. T. U. per hour $= 830 \times 152 = 126{,}160$.

Difference between the average temperature of the water and the temperature of the steam = $228 - 114 = 114$ degrees.

B. T. U. given up to the water per square foot of surface per hour = $114 \times 200 = 22{,}800$. Therefore,

Number of feet of heating surface required = $126{,}160 \div 22{,}800 = 5.5$ square feet of surface or 12.6 lineal feet of 1¼-inch, or 16 lineal feet of 1-inch pipe.

EXAMPLES FOR PRACTICE

1. How many linear feet of 1-inch iron pipe will be required to heat 150 gallons of water per hour from 40 to 200 degrees, with steam at 20 pounds' pressure? Ans. 21.3 feet.

2. How many square feet of grate surface will be required in a heater to heat 300 gallons of water per hour from 50 to 170 degrees? Ans. 7.4 sq. ft.

3. A hot-water storage tank has a steam coil consisting of 30 linear feet of 1-inch iron pipe. It is desired to connect a coal-burning heater for summer use, which shall have the same capacity. Steam

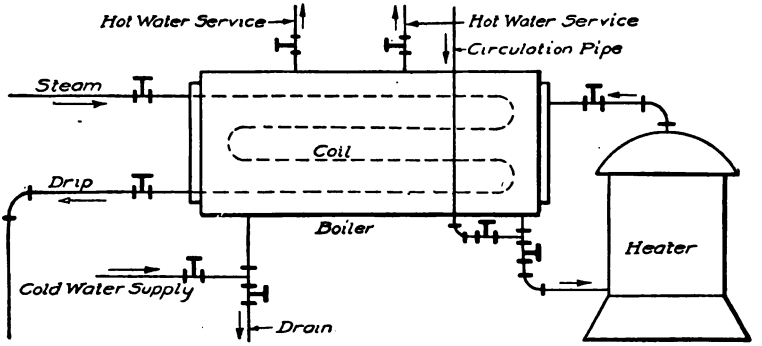


Fig. 11. Storage Tank Heated by Steam Coil in Winter; Cross-Connected to Coal Heater in Summer.

at 5 pounds' pressure is used, and the water is raised from 40 to 180 degrees. How many square feet of grate surface are required? Ans. 5.9 sq. ft.

4. A hotel has 30 bathtubs, which are used three times apiece between the hours of seven and nine in the morning. The hot-water system has a storage tank of 400 gallons. Allowing 20 gallons per bath, and starting with the tank full of hot water, how many square feet of grate surface will be required to heat the additional quantity of water within the stated time, if the tempearture is raised from 50 to 130 degrees? Ans. 11.6 sq. ft.

If steam at 10 pounds' pressure is used instead of the heater, how many square feet of heating coil will be required? Ans. 15.3 sq. ft.

Calculating Coil Surface. Heat transmission from steam to water in iron pipe increases with temperature difference from 150 B.t.u.

per square foot, per hour per degree for 100° difference, to 228 B.T.U. for 125° difference. The relative condensing power of submerged iron, brass, and copper pipe is about as 2, 4, and 5, respectively. Within the range of water temperatures usual in practice and with steam at ordinary pressure, we may safely place the condensing power of iron, brass, and copper pipe in even tenths, .2, .4, and .5 pounds per hour, per square foot, per degree difference between the steam and mean temperature of the water. With these values, the latent heat of steam, say 960, should be used in converting heat units, found as in preceding examples, into "pounds" of steam. Having this latter, the process of finding the coil surface would be: multiply the temperature difference by the constant .2, .4, or .5, according to the kind of pipe coil to be used, and divide the "pounds" of steam by the product so obtained. The result will be coil surface in square feet, which may be converted into lineal feet by multiplying by 2.9 for 1-inch pipe; by 2.3 for 1¼-inch pipe; by 2.0 for 1½-inch pipe, and by 1.6 for 2-inch pipe. As in some of the previous examples three feet of 1-inch pipe are generally taken as one square foot. Sometimes a storage tank

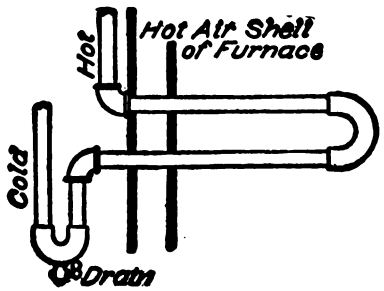


Fig. 12. Cross-Connection of Storage Tank to Firepot of Furnace

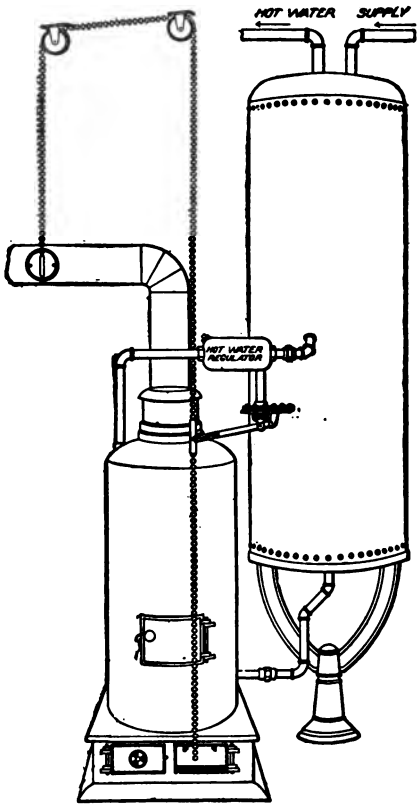


Fig. 13. Temperature Regulator Attached to Coal Heater.

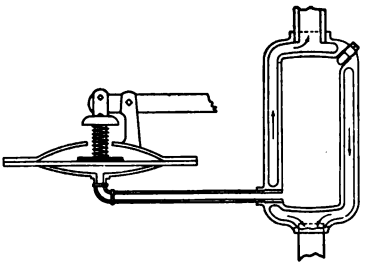


Fig. 14. Steam Generator of Temperature Regulator Shown in Fig. 13

is connected with a steam-heating system for winter use, and cross-connected with a coal-burning heater for summer use when steam is not available. Such an arrangement is shown in Fig. 11. A cross-connection for the same purpose is often made to the fire-pot of the house-warming heater,

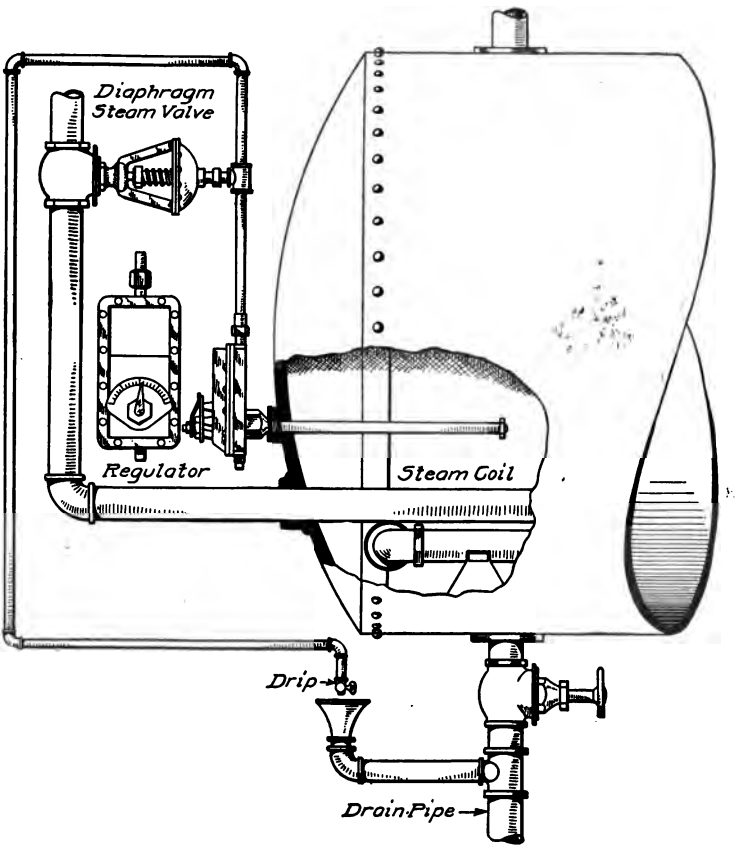


Fig. 15. Temperature Regulator Connected to Steam Coil

as indicated in Fig. 12. A drain at the lowest point is essential, but a dip as deep as the one shown is not necessary.

Temperature Regulation. Hot-water storage tanks having special heaters or steam coils should be provided with some means for regulating the water temperature. Figs. 13 and 14 show a simple form attached to a coal-burning heater. An outer shell is connected with the circulation pipe as shown in Fig. 13. An inner chamber connects with a space below a flexible rubber diaphragm in a separate case adapted to operate the draft lever.

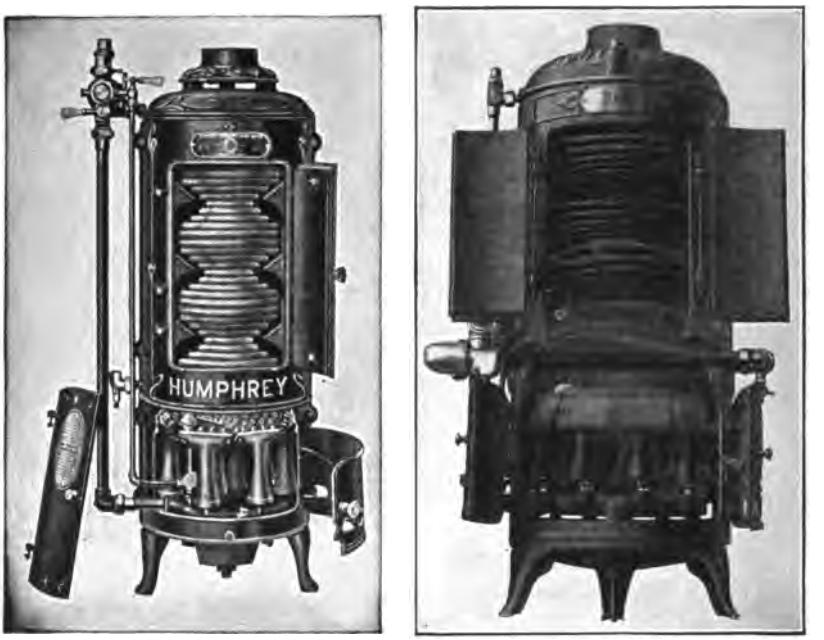


Fig. 16. Typical Automatic Gas Heaters for Instantaneous Hot-Water Service
Left—Humphrey Heater; Right—Ruud Heater.

A form of regulator for use with a steam coil is shown in Fig. 15. This consists of a rod made up of two metals having different coefficients of expansion, and so arranged that the difference in expansion will produce sufficient movement to open a small valve when the water reaches a given temperature. This allows water pressure from the street main with which it is connected, to flow into a chamber above a rubber diaphragm, thus closing the steam supply to the coil. When the water cools, the rod contracts, and the pressure is released above the diaphragm, the valve opening to admit steam again.

Return circulation is provided in these installations in the way already described, being even more essential than in small jobs with shorter runs and fewer fixtures; yet one would think that the great number of fixtures served would insure at least one or another being in constant use, and thus keep warm water in the main lines without special provision for the purpose.

In cottages with no bath and with small culinary requirements,

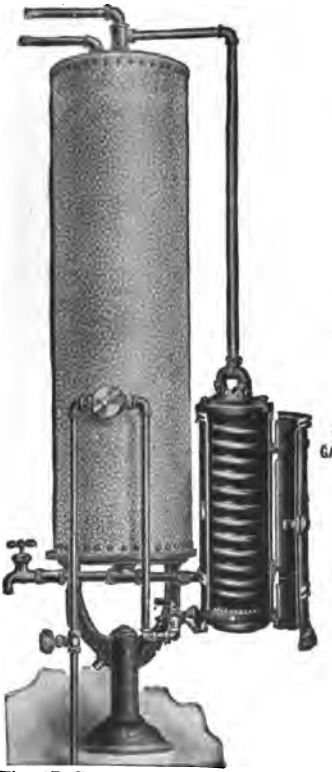


Fig. 17. Crane Gas Heater Connected to Range Boiler Controlled by Thermostatic Valve.

Fig. 18. "Lawson" Combination Gas Heater and Range Boiler Thermostatic Control Valve at Left.
Courtesy of Crane Company, Chicago

a 30-gallon reservcir is sufficient. Not less than 40 gallons should be employed for a bathroom job. The capacity of the average stove heater is even too great for 40 gallons' storage unless there is liberal use of hot water; but where gas is used and the water heating independent of the cooking heat, as it generally is, the temperature can be regulated to suit. A storage capacity of 52 gallons or more is usual for large residences.

Gas Heaters. There are gas heaters provided with thermostatic or pressure mechanism by which the hot service is taken care of automatically. The latter of these are simply connected in the line in a convenient place, and operated by a differential valve. Their appearance is shown in Fig. 16. Simply opening any hot-water faucet reduces the pressure, and the gas is thereby turned on full as

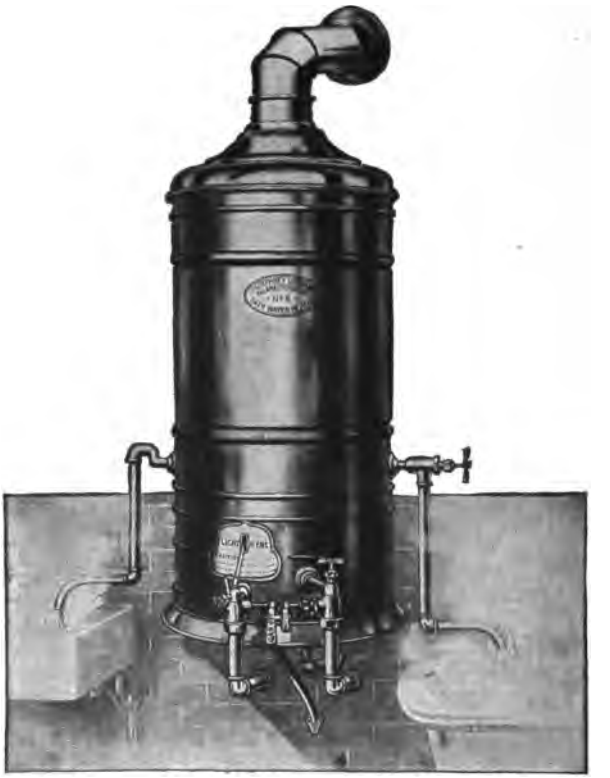


Fig. 19. Instantaneous Gas Heater Connected to Gas Supply Pipe and Operated Directly in Bathroom.
Courtesy of The Humphrey Company, Kalamazoo, Michigan.

long as water is drawn. A pilot light ignites it, and the supply is heated as fast as it passes through the copper coils of the heater. No storage capacity is required by this form. In another form, shown in Fig. 17, the heater is controlled by a thermostatic valve projecting into the regular reservoir used with it. When the water in the reservoir is heated to the desired temperature, the gas supply is reduced or cut off. In Fig. 18 is shown in part section the "Lawson"

combination gas heater and range boiler. This is a very reliable heater and is very well designed. The copper-tube coil forms the direct heating surface, having water connections at both top and bottom of the boiler. The thermostatic valve shown at the left regulates the gas consumption. Drawing water from the hot faucets lowers the temperature in the reservoir through the cooling influence of the incoming water, and the thermostatic principle is again made to serve in opening the gas-valve until the water is heated to the desired temperature.

There are other arrangements consisting essentially of an encased copper coil, above a gas-burner, connected to a standard reservoir at top and bottom. In these, the gas is turned on and regulated by hand as nearly as possible to suit the needs.

Fig. 20. Sectional View of Humphrey Heater Shown in Fig. 19

Instantaneous water heaters, operated by gas or gasoline, and placed in proximity to the fixtures served, as shown in Fig. 19, so as to deliver the heated water directly, are in general use where local conditions favor them. These have have no storage capacity. A sectional view of Fig. 19 is shown in Fig. 20. In this heater, the water is not exposed directly to the heated air and gases, and water so heated is suitable for use for any purpose so far as the method of heating is concerned. The purposes for which water heated in contact with the gases of combustion may be used are limited.

Other heaters of this class offer admirable means for the water to take up the heat generated by the gas. All of these special means of heating water—especially those not conforming to the plumber's regular routine—are best understood and judged by a close study of the literature supplied by the makers.

Avoiding Lime Deposit. Where lime or other deposits choke the water back and connections as ordinarily installed, both the annoyance and the danger may be avoided by following the plan

shown in Fig. 21, in which the water is heated by water by conduction through a coil in the reservoir. The water back is connected to the coil; and an expansion tank, piped as shown, is provided to take care of the expansion of the water in the primary heater or water back. Distilled water is used in the back to avoid incrustation of the back and connections. *C* is the tank, which must be filled to above the flow connection. *G* is tank return; *D*, the drain to water back and connections; *E*, a sediment cock on the reservoir proper. The flow from upper water back connection to the expansion tank should be at least one size less than either the coil in the reservoir or its connections.

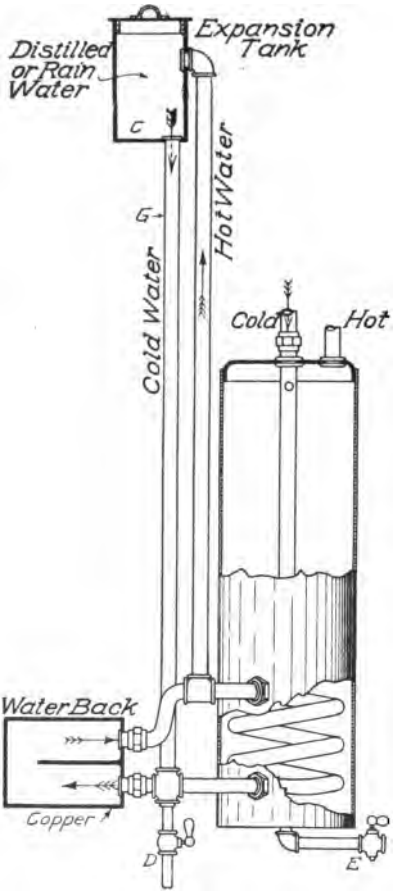


Fig. 21. Reservoir Heated by Hot-Water Coil Connected to Water Back, Avoiding Choking from Lime or Other Deposits

Two Heaters to One Boiler. Occasionally two heaters are connected to one boiler as shown in Fig. 22. In this instance it is assumed that the house is heated from a furnace in the basement and a coil is fixed in the heater, while hot water may be derived from the water back in the range at the same time. This procedure gives a greater volume of hot water and, in a temporary hard-water district, one heater may be put out of action and the incrusted deposit removed without interfering with the hot-water supply derived from the other heater. To accomplish this, however, stop cocks are required on each pair of circulation pipes. Obviously, this is a very dangerous practice and, where adopted, only stop cocks with square heads and loose keys should be used. Further, they should be

tightened in such a manner that it is impossible for anyone other than a proficient authorized person to manipulate them.

Practically the same idea is shown in Fig. 23, where both the water back and independent heater are connected to one boiler. This is very good practice for those buildings requiring an unusual quantity of hot water one day per week and a normal quantity the rest of the time.

Two or More Boilers to One Heater. Where an efficient heater is installed and the storage capacity in the boiler is inad-

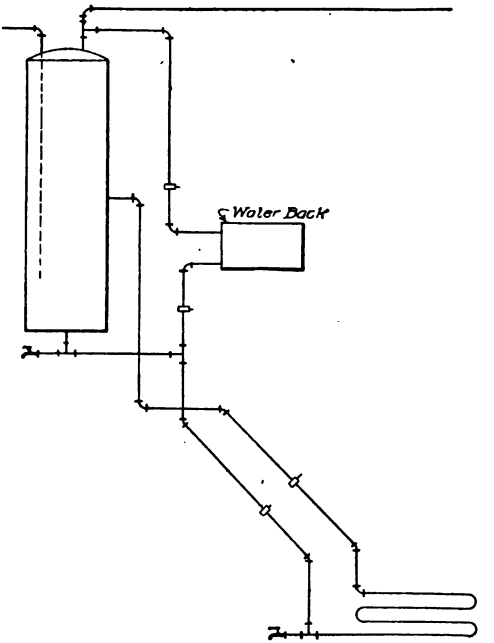


Fig. 22. Layout in Which Two Heaters Are Connected to One Boiler

equate, or in those buildings requiring quantities of water on fixed days out of all proportion with the ordinary demand, two, three, or more boilers can be connected to one heater as shown in Fig. 24. This method is also serviceable in large country houses where one boiler is sufficient most of the time, yet when house parties are held, three times the storage capacity is necessary to insure satisfaction. Stop cocks must be fixed on each pair of the circulation pipes so that one or two of the boilers can be put out of com-

mission when not required. The danger of explosion through the cocks is not so great as in the former method, as all six cocks would have to be closed at one time before the danger zone was reached. However, they should not be tampered with in any way by anyone but a competent person.

Collapsing of Boilers. It is not uncommon for boilers to collapse during the winter months, the chief danger being from

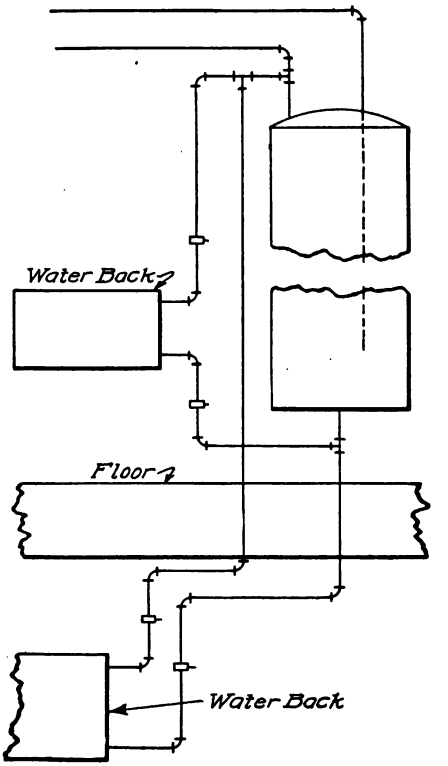


Fig. 23. Layout in Which Water Back and Independent Heater Are Connected to One Boiler

frost. The collapsing of the boiler most frequently happens in the gravity supply where the expansion pipe is discharged into the supply tank, which is oftentimes exposed to frost. The collapsing of the boiler used for domestic hot-water supply may be explained in this manner. During the winter season a large fire is kept in the cooking range, causing the water in the heater

and in the boiler to attain a very high temperature. The water in the heater, circulating pipes, and boiler expands considerably, owing to the increase of temperature, and in expanding rises in the expansion pipe. The water is now frequently emitted in spasmodic spurts from this pipe which is terminated over the

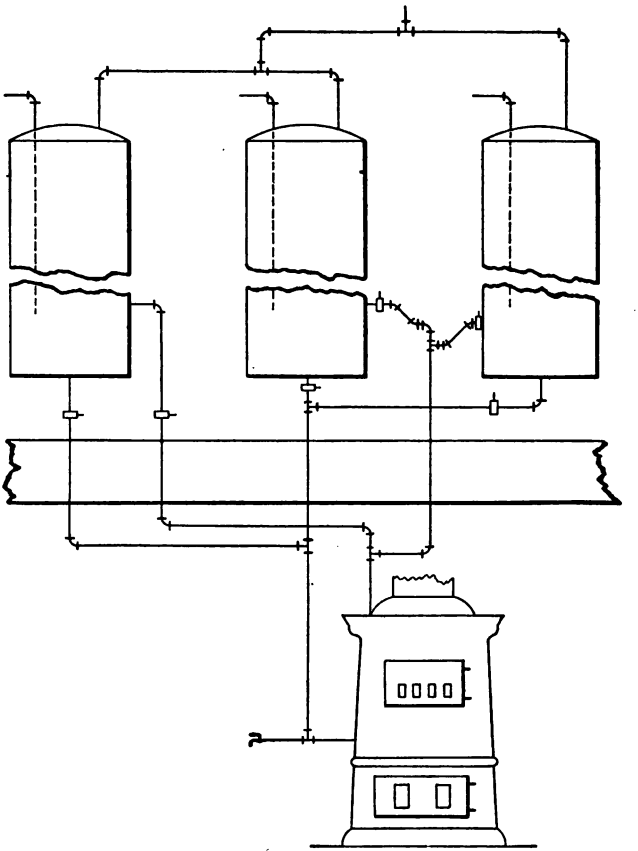


Fig. 24. Layout in Which Two or More Boilers Are Attached to One Heater

tank. It being a frosty night and the tanks being in an exposed position, the water cools and solidifies gradually at the outlet of the expansion pipe, until it becomes hermetically sealed; at the same time the supply pipe to the boiler also becomes stopped by frost. The fire in the heater is now allowed to die out and while cooling the water also contracts both in the heater and

boiler, and in so doing a partial vacuum is formed in the boiler. Now when this reduction of internal pressure takes place, the external atmospheric pressure is such that the material of which the boiler is constructed is not sufficiently strong to withstand the enormous external pressure exerted on the boiler, with the result that the body or sides of the boiler are crushed in or, in other words, the boiler collapses.

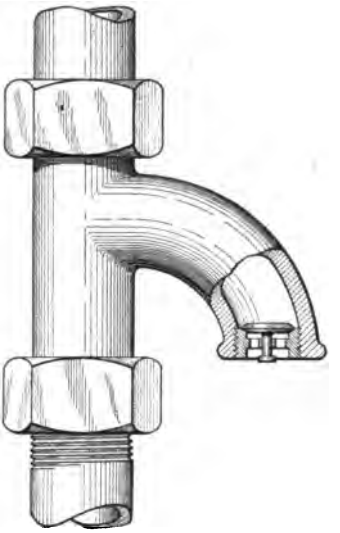


Fig. 25. Vacuum Valve to Prevent Boiler Collapse

Fig. 25 shows a vacuum valve which should be placed in the hot supply pipe to the fixtures, as close to the boiler as practicable. Under normal conditions, the water pressure in the systems keeps the valve closed, but as soon as a partial vacuum forms in the boiler, the external atmospheric pressure of 15 pounds per square inch exerted on the valve opens it and allows air to find its way into the boiler, thus equalizing the internal and external atmospheric pressure, which obviates the collapsing of the boiler.

DESIGNS FOR DOORKNOCKERS

R. Binet, Architect, Paris, France.

Reproduced from "Esquisses Décoratives de Binet, Architecte."

HARDWARE

Introductory. Hardware in building is generally considered to embrace all metallic appliances of a mechanical nature. For example nails, screws binding the various parts together, hinges permitting movement, and locks to secure moving parts in place, are all in the nature of mechanical appliances. Ornamental metallic parts, such as railings, grilles, steps, etc., cannot be classed under this head.

There is no other division of building materials in which the variety is so great or the range of each variety so wide. The distance, for example, separating the cast-iron lock (Fig. 1), at one dollar and a-quarter a dozen, from the cylinder front-door lock (Fig. 2), at seventy-five dollars a dozen, is great. If, however, we were to trace the evolution from the one to the other, we should find that the extremes are connected by such fine gradations and steps that nowhere can any break in type be detected: there is no missing link.

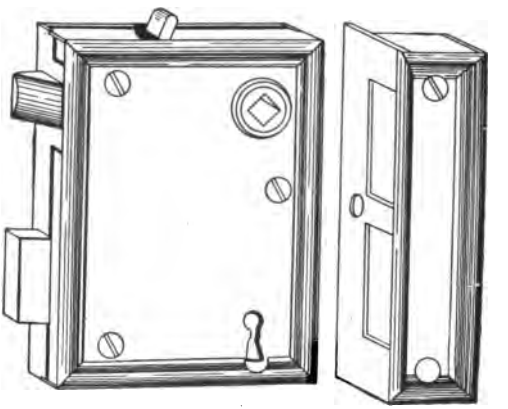


Fig. 1. Cheap Cast-Iron Lock.

The same conditions in varying extent apply to all other classes of hardware—hinges, bolts, etc.—and to a buyer who consults catalogues, comes the further complication that all items are sold, not according to the *price list*, but on *discounts* from such lists. The word *discounts* is here used advisedly, for there is no one, single discount applied to all classes of hardware. For different types of appliances, there are different discounts. Some items are sold as high as 10 per cent off; the next may carry a discount of 75 per cent;

and, between these, discounts are varied and graded as delicately as are the types themselves.

Time has had a marked effect in changing the character of hardware. The latches, knockers, or locks of 150 years back are very different from any of the types characteristic of today; and while the imitations which can now be made are good in their way, still nowhere

Fig. 2. Cylinder Front-Door Lock

in the 150 years is there a marked break in the line of development from the prized antique to the best production of the present day.

As a plain example, take the nails and bolts forged in the "factory" of Jefferson at Monticello, and nearly one hundred years ago used in the trusses over the old Senate Chamber at the Capitol in Washington (Fig. 3); compare them with those in use today, and then try to have duplicates forged; and the difficulty of getting the spirit of the past, even in simple things, will be appreciated.

Nationality serves also to bring the changes. The French artisan will make a delicate but strong appliance which reflects unconsciously the influence of the objects of art with which he can and does daily come in contact. The Louvre, with its innumerable treasures of art—freely open to the street-sweeper in his blouse, as well as to the rich—has its effect on national production.

The English, from the same design, will produce something not so delicate, nor with such an artistic "go"; but it will be strong, heavy—in fact, English.

Fig. 3. "Jefferson" Nails and Bolts
From Trusses of Old Senate Chamber in Capitol, Washington, D. C.

The American will make the best reproduction of the design it is possible to get from his machinery in large lots; but it often lacks the fine touch of the artist, which the French impart, or the evident firmness of purpose of the English.

It will not be the province of this paper to settle the style or kind of hardware which should be selected by people of different temperaments, or to suit any design; individual tastes and judgment must in each case govern; but it will be its province, in a general way, to point out the characteristics of the material now obtainable, the intention being to offer something more in the nature of suggestion than as an absolute guide.

NAILS AND SCREWS

These embrace the class of most uninteresting hardware—so commonplace as hardly to demand attention; but they play, after all, a large part in modern construction, and have had the greatest influence in the evolution of the now almost extinct trade of joinery, as understood a hundred years ago.

By reference to the cut of the "Jefferson" nail (Fig. 3), it will be seen that it is a wedge more adapted to splitting all wood through which it is driven than to make the parts more secure. It was the successor of the oak pin of Colonial days, and was used in much the same way. After the parts were most carefully fitted together, holes were bored only slightly smaller than the nail, and the latter was driven in to secure the close contact of the parts, which, indeed, were already fitted so nicely that they would cling together with a very slight binder.

Fig.4. End of a Piece of Old Timber from Capitol, Washington, D. C., Showing Former Method of Making Spliced Joint.

Fig. 4 is the end of a timber taken from the Capitol, which shows how the splice joint was made; this was a *joiner's* fit, which took very little to complete the union. Through all the work of joinery—illustrated by this close fitting—the same principles extended, so that the use of nails of the Jefferson type was very limited.

Screws, except in very crude forms, were seldom used. Fig. 3 shows bolts and a nut of the same period taken from the Capitol trusses. It will be noted that in order to make their use possible, the parts must have been accurately fitted.

With modern machinery for making nails and screws, came a revolution in carpentry work. The old mortise-and-tenon timber frame gave way to the balloon frame. Joinery died a natural death, as it was found much cheaper simply to lay the pieces together and drive spikes or nails until the whole was solid. In many instances the use of spikes or nails was carried to extremes—in fact, their use became

reckless; and so important is their place in construction work, even to-day, that it is a by-word, that "any man is a carpenter who can drive a nail." But the man who can select the right nail or screw, and drive it where it is needed, and in the right way, is a rare man.

From the strictly practical standpoint, nails and screws may be divided into two classes—*First*, those used in construction work only; *second*, those used in construction work so exposed as to require consideration of the appearances they present.

For the first, round wire nails are now used almost exclusively. The older cut nail is wedge-shaped, with two rough sides, which make it hard to drive and which tear the fibre of the wood; the wedge shape, moreover, permits these nails, after they are once started, to be more easily drawn out. The wire nail is smooth, does not tear the wood, and is more easily driven than the wedge; and, on account of being of the same diameter throughout, it holds firmly even after being started in withdrawal.

A nail should never be driven clear through any woodwork so that the point appears, unless it is *clinched*, in which case a wrought-iron or "clout" nail is required; the wire nail is too hard to be easily bent and clinched. A nail driven clear through so as to expose the point unclinched will not hold so well as one shorter with the end buried.

In the frame, it is not the number of nails that tells, but their careful placing in such parts and at such points as to keep the building stiff. Nails should be grouped to afford the largest efficiency. In nailing the boarding onto a frame, for example, it is necessary to put two nails in each board to each stud. One nail would be sufficient to secure the boards; but, as there is bound to be a slight shrinkage drawing the edges of the boards apart, if the frame is not otherwise securely braced, a strong wind will rack the structure out of plumb until the edges of the boards touch again, the single nail in each board allowing a swing which would have been effectually stopped by two.

The smallest nail competent to accomplish the purpose should be used, on account of the greater ease with which it can be driven; the difference in effort required to drive ten thousand 20d nails and an equal number of 16d's is a very material item in expense.

When strength is obtained by doubling timbers and in trusses,

bolts and nuts with large washers should be used to the exclusion of nails, as a sudden jar or a slight shrinkage of the wood will prevent the nails clamping the parts closely together, and this separation or loosening of the joints materially reduces stiffness and strength.

The use of wrought-iron nails can with great profit be extended. For instance, after a house is boarded up and building paper put on, in placing the exterior finish boarding, of whatever nature it may be, if the nails are clinched on the inside, the contact will be so close as to prevent the opening of cracks between the layers, and in cold weather the nails will not "draw" and allow the joints to open.

Where nails must be used in finished surfaces, all questions of general construction must be dropped, and only such nails used as are absolutely necessary to secure the members in place; and special attention should be given to selecting nails with such heads as will not disfigure the finish. Wire nails of very small diameter and with heads only slightly larger in size, are now made; and it is remarkable how firmly these hold the parts in place. These nails, carefully driven and with heads *set* below the surface of the finish, leave a small mark that can be readily hidden with putty colored to match the tone of the wood.

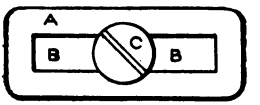


Fig. 5. Round-Head Screw with Washer.

Wherever possible, nails should be put in the quirks or concealed places, rather than in plain surfaces where the last blow of the hammer is apt to leave a round indentation in the wood. A careful carpenter in good work can place his finish so that it can be either nailed or screwed in place from the back, or the nails or screws placed so that the heads will be covered or in inconspicuous places.

In purely constructive work, screws (unless as bolts) are little used except in special finish, such as mantels and other cabinet-work put together and finished complete before being set in place.

When it is necessary to provide for the shrinking and swelling of the woodwork, round-head screws with washers can be used. Fig. 5 illustrates such a screw, *A* being the washer; *B* a long slot, and *C* the screw; this arrangement allows movement with the screw sliding on the washer.

When it is necessary to use screws in finished surfaces, the treatment should be exactly the reverse of that governing the use of nails.

There are many forms of screws on the market, with well-formed heads, finished in lacquer, blued, or plated (it is necessary to have *some* finish to prevent rust). A variety of typical forms are shown in Fig. 6. The custom of starting screws with a hammer—in

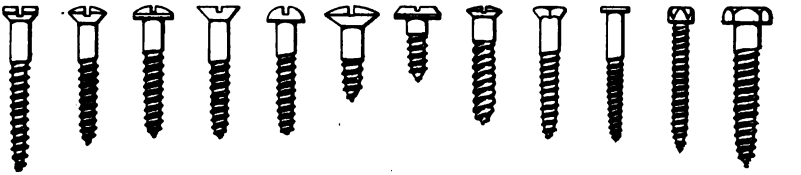


Fig. 6. Typical Forms of Screws.

fact, driving them three-quarters of the way in—should not be allowed; a screw with a battered head or not driven in straight, disfigures the work; when started by the hammer, one or both of these conditions generally prevail.

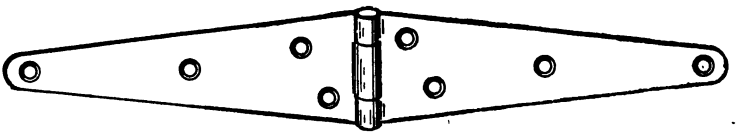


Fig. 7. Strap Hinge.

Screws which show should have heads of pronounced shape, spaced regularly—in fact, made a feature in the design.

HINGES AND BUTTS

This group of hardware is the most important on the list, for

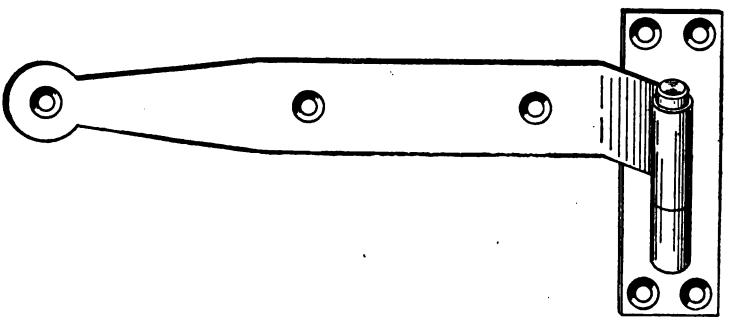


Fig. 8. Tee-Hinge with Offset.

if the hinge is out of order or lacking, the door is absolutely useless. It matters little if the latch, lock, or bolt be missing; some simple

device will supply the lock and produce the results usually obtained from the missing fixture. Without hinges, however, the door cannot be operated.

Hinges, properly speaking, consist in those appliances which are secured on the *faces* of the door and frame. Unfortunately they are now made, for the most part, in only the cheap grades, being used on barns and gates and in other inferior locations, and are known as *strap hinges* (Fig. 7) or *tee-hinges* (Fig. 8), etc.

The possibility of their artistic use is shown in the fact that manufacturers of high-grade hardware make a variety of *hinge plates* (Fig. 9) to be screwed on the face of door and frame independent of the butt, to represent the complete hinge.

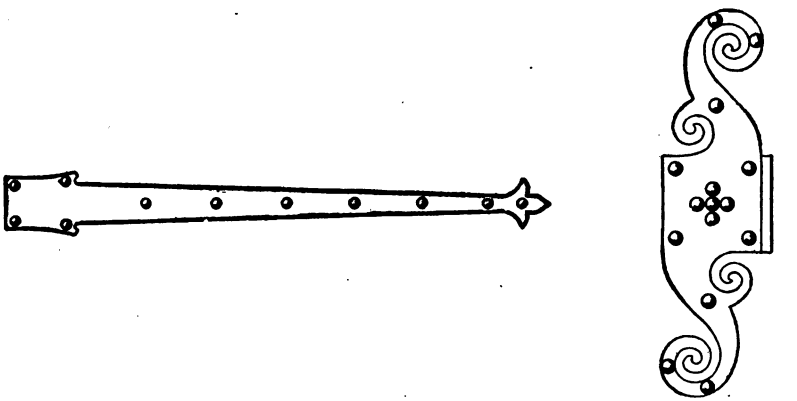


Fig. 9. Hinge Plates.

It is unfortunate that the hinge proper has dropped so completely out of the house hardware list. In its simple forms it has character and dignity. Some of the best efforts of the Gothic builders and the metal workers of the most artistic periods, have been put forth to produce hinges of perfect workmanship and design. The attempt of the manufacturers to supply the appearance by making the plates separate, has led to the production of unduly elaborated face-plates of thin metal, which are often screwed on without reference to their suitability to the location or surroundings, so that, instead of having the appearance of being a minor item for use in swinging the door, they give the impression that the door is for the special purpose of exhibiting the hardware.

The simple barn hinge may occasionally be used with propriety and good artistic effect. Fig. 10 shows a common form of the hinge on a house door where the finished timbers show throughout. These hinges are fastened by small lag-screws, and, while inexpensive, give a very artistic air to a common stock door. But there is difficulty when such appliances are used, in finding other fixtures to carry out the idea. In the case above referred to, it was necessary to have a latch forged specially (Fig. 11), as nothing suitable of stock pattern could be found.

Fig. 10. Barn Hinge Used on House Door.

The *butt* (Fig. 12) is that style of hinge (butt hinge) commonly used in swinging doors, sashes, etc., which is screwed to the butt edge of the door and which can be fully seen only when the door is open; when shut, only the knuckles of the butt are visible.

Fig. 11. Forged Latch to Accompany Hinge of Fig. 10.

Modern custom requires, in the large majority of cases, that the conventional butt be used, and it should receive the careful consideration of the designer. There are many efforts to give ornamental effects, even in the cheapest of cast-iron butts, by working patterns on the parts never seen except when the door is wide open, and by making ornamental tips on the pin which fastens the two halves together. These attempts are unfortunate, generally serving merely to emphasize the cheap character of the article; and the plain black,

smooth surface is always to be preferred. With slight modifications, these objections may be raised against almost all attempts to make ornamental butts in other materials.

Door Butts (and this is, so far, the largest class) are made of steel, cast iron, brass, or bronze, the expense increasing in that order. The cast-iron butt is much used. In Fig. 13 is shown a very good type of loose-pin butt made in brass or bronze, with steel or fiber washers introduced between the knuckles to prevent wear.

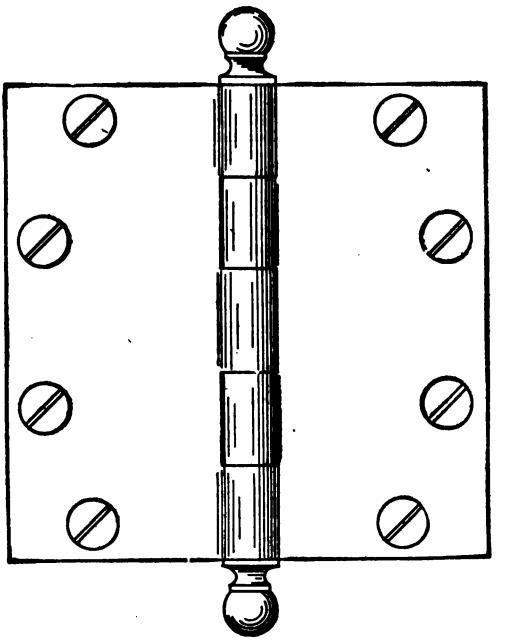


Fig. 12. Plain Butt, Loose-Pin Type.

Fig. 14 shows the ordinary type of a *five-knuckled loose-pin wrought-steel butt.* The knuckles are marked *A*.

If the door is hung to the wing *E*, it is evident that the bearing points of the butt will be at *B*, *B;* if the door is hung on the wing marked *F*, the bearing points will be *C*, *C*. *D* is the head of the *loose pin*, which extends through the knuckles, as indicated by dotted lines; this can be withdrawn when it is desired to take down the door.

For ordinary doors the butt should not be less than four inches high, with five knuckles to each butt for the loose-pin type. An examination will show that there are always two bearings on each five-knuckled butt, so that if there are three butts to a door there are always six bearing points; and when the weight of the door is considered, with the fact that all this weight is carried from one side, the necessity for ample bearings will be appreciated. The loose pin allows the doors to be taken down readily; and when, from excessive use, the bearings have become worn, it also allows the placing of steel

washers (Fig. 15) between the knuckles, to take up the worn portions.

Wrought-steel butts can be had in plain material and fair workmanship, 4 by 4 inches, as low as $1.30 a dozen pairs, with screws; and from that up to $7.00 a dozen fitted with ball bearings and bronze-plated. The best grade of what is commonly known as the *Stanley* butt is a good example of this type. Butts are now often made with ball-bearing washers (Fig. 16), mounted in place of the steel or fiber washers shown in Fig. 13. These greatly improve the wearing qualities of the butts and make the door swing easier.

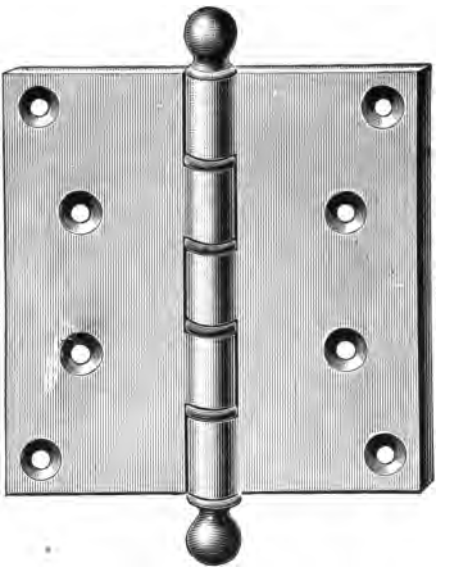


Fig. 13. Sargent Brass or Bronze Loose-Pin Butt with Steel or Fiber Washers

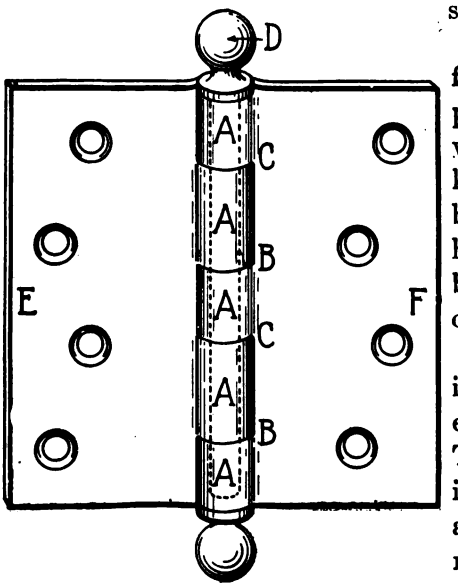


Fig. 14. Common Five-Knuckled Loose-Pin Butt.

Cast-iron butts are also finished in various ways (especially in *Bower Barff*, to which finish reference is made later), and in fact can be combined with almost any line of hardware finish. They are to be recommended on account of their mechanical perfection.

Cast brass or bronze is used in expensive work, but to be efficient must be *very heavy*. The material is softer than iron; and if the bearing parts are not protected, they wear rapidly; a drop of one thirty-second of an inch in the

door on account of such wear, will at once cause inconvenience.

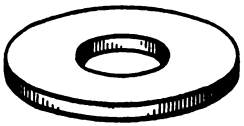


Fig. 15. Steel Washer for Butt.

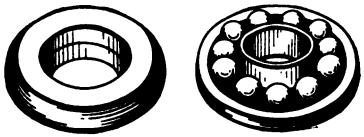


Fig. 16. Ball Bearings for Butt.

The protection against wearing of the knuckles may be by ball bearings, as above shown (Fig. 16), or, as in the more general practice, by *bushings* consisting of thin steel plates (as shown by the stippled part in Fig. 17) set in each face of each knuckle so that they receive all the wear and relieve the softer metal. In these plates are slight indentations (not stippled) which hold oil for an indefinite period. This oil lubricates the bearings. Often the knuckles are bored out, and a steel cylinder inserted as a bushing.

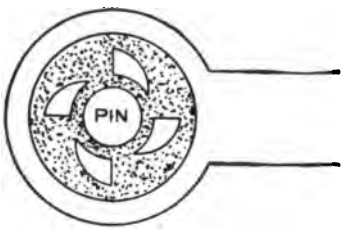


Fig. 17. Steel Plate Bushing Used between Butt Knuckles.

When it is advisable to use real bronze for butts, expense should not be spared to get the best from a mechanical standpoint. It is always a safe rule to get the cheaper material with perfect workmanship, rather than expensive material of indifferent workmanship.

There are many "ornamental" brass and bronze butts made by casting designs on the surface and emphasizing the effect by polishing the raised parts.

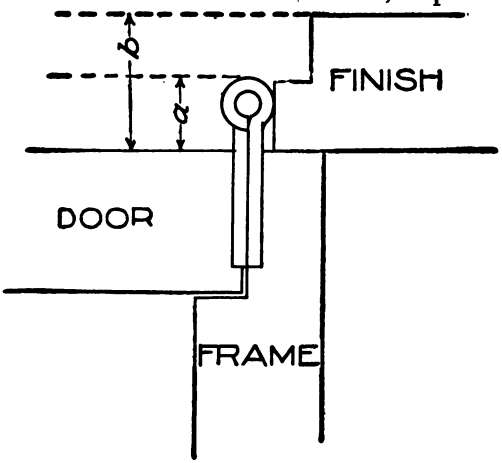


Fig. 18. Showing Necessity for Projection of Door Butt.

This does not add to the distinctness of the design, and only leaves the impression of a "well-broken" surface. *It will be noted that, in general, the plainer the butt, the higher the price, and the highest grades of butts are rarely of the ornamental variety.*

There is little ornamental value in the knuckles of a butt. A butt should, therefore, be of such a size as to project as little as possible beyond the door or frame.. The only point to be carefully seen to, is that it shall extend outward far enough to throw the door clear of the trim or woodwork at the side. Thus the projection at *a*, Fig. 18, should be a trifle more than one-half the distance *b*, in order to carry the door, when opened back, clear of the side trim.

After the decision relative to the *style* of hinges or butts to be used is made, the closest attention should be given to the *mechanism.* A door in common use will wear its hinges with astonishing rapidity. Three hinges should always be used on a door. The third hinge, or the one at half the height, keeps the door from springing, and relieves the strain on the other two, so that the door is more easily operated; and it also gives 50 per cent additional wearing resistance.

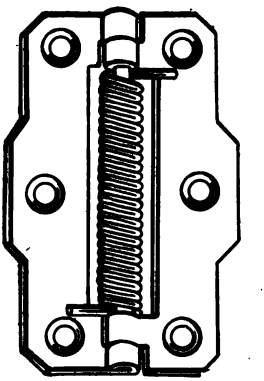


Fig. 19. Cheap Type of Spring Butt.

The same reason for using loose-pin butts as above given for doors, apply to the hanging of all items swinging on upright bearings—such as cupboard doors, window-sash, etc.; and it is sometimes necessary to use much care in the selection, in order that the swinging parts may turn clear of all obstructions or fold back on themselves, as with inside blinds.

Where the swing is from horizontal bearings, the pins should always be *fixed*—that is, so made that they cannot be removed. In an upright position gravity holds them in place; but when put horizontally, the swinging of the sash works the pin loose, and in time it is apt to fall out and allow the sash to drop, this being the case particularly in swinging transom sash.

Besides the types of butts above referred to, there are many

appliances properly classed under this head designed for special service, such as *spring butts* and *double-acting butts*.

Spring Butts. Spring butts are those in which a spring is placed so as to force the door closed when not held open by some other force. These vary from the light type commonly used on wire-screen doors, costing from 10 to 15 cents a pair (Fig. 19), to heavy bronze butts with a high-grade metal spring in the joint, costing $5.00 a pair (Fig. 20), which can be regulated to give either a strong or a light reaction.

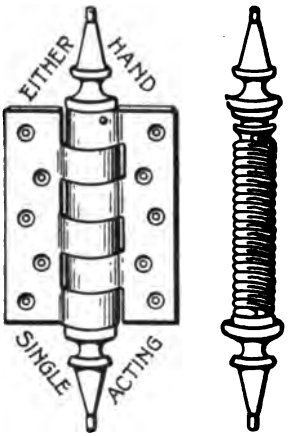


Fig. 20. Heavy Bronze Spring Butt.

The disadvantages of this type are that they rack the door by constant slamming; they are much more expensive than butts of the same material without the spring; and when once installed, it is practically impossible to throw the spring out of service. For the light and cheaper work, a single spiral spring (Fig. 21), costing from 15 to 25 cents, can be used independently of the butt; it is easily unhooked when not needed.

For the better grades of work and heavier doors, a spring check should be used (such as is described under *Miscellaneous Hardware*), which will close the door promptly and prevent slamming.

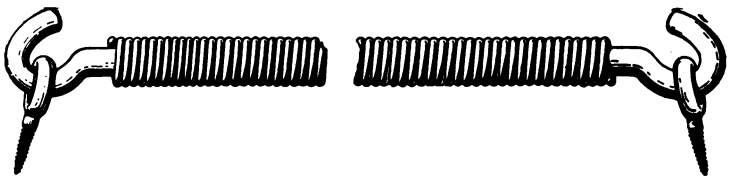


Fig. 21. Common Type of Spiral Spring for Doors.

Double-Acting Butts. The function of the double-acting butt is to allow the door to swing to both sides of the jamb. It is necessarily of the spring-butt type, above mentioned, but is double and is so set as to leave the door shut when at rest. There are no cheap types of this butt on the market, and the work required makes the best mechanism necessary. There are no appliances which can be sub-

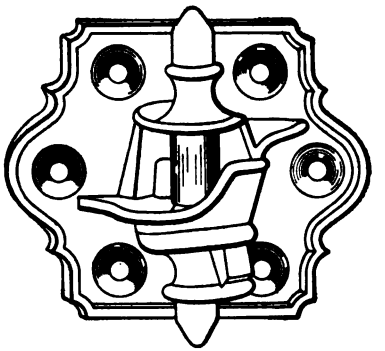


Fig. 23. Gravity Blind Hinge.

In selecting double-acting butts, always get a large size capable of doing the work easily, as the jar on a light butt as the door passes the closed point will quickly rack a light appliance into a useless condition. In house building, the use of double-acting springs is usually confined to china-closet doors, and in public buildings to entrance doors. In a very large number of cases a little study will devise means of substituting simpler appliances. For a public building, for example, two single-acting doors can be used—one for entering and the other for outgoing traffic.

Blind Hinges. Outside *blind hinges* are important items, especially in rural districts in the North and stituted as in the case of simple single-spring hinges. In order to do the work satisfactorily, a very large hinge is required—too large to be ornamental—so that certain types are embedded in the floor, out of sight; these are peculiarly adapted to heavy doors when the floors are of Mosaic so that the hinge can be firmly bedded in concrete.

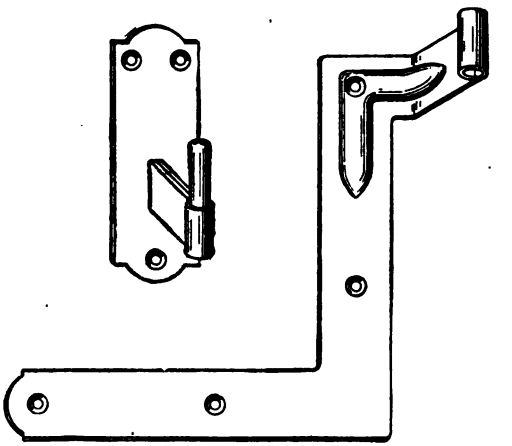


Fig. 23. Wrought-Iron Blind Hinge.

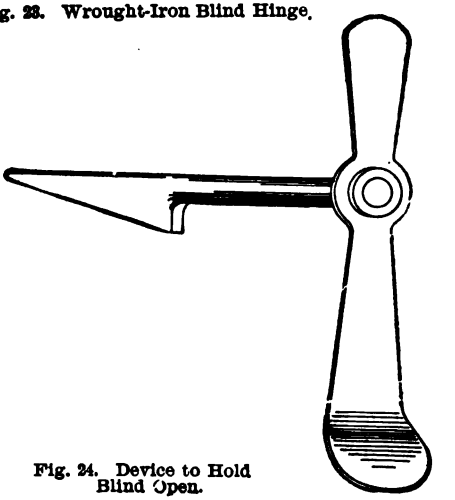


Fig. 24. Device to Hold Blind Open.

throughout the South, where blinds are a necessity. The usual cast-iron *gravity blind hinge* (Fig. 22) is a very cheap and unsatisfactory fixture. The smallest jar or blow will break hinges of this type. A heavy wind, catching the blind, will often slam it with sufficient force to break the window glass. It is much better to procure some type of wrought-iron hinge (Fig. 23),

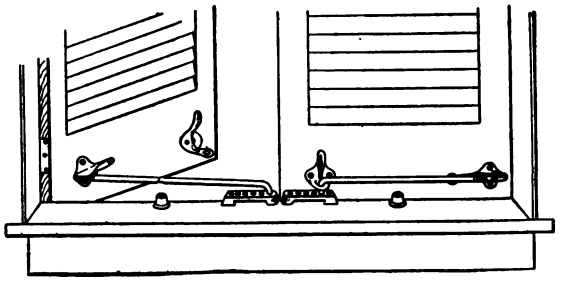


Fig. 25. Blind Adjuster.

and a separate appliance to hold the blind open (Fig. 24). This type of hinge is also rather ornamental, the part fastened to the face of the blind being in the true sense of the term a hinge-plate.

A *blind adjuster* is indicated in Fig. 25. There are several appliances on the market which accomplish the same result — that is, holding the blinds secure at any angle up to about 60° from the sash plane. It is very desirable to install these fixtures —which are strong, and which hold the blind firmly—where blinds with fixed slats rather than rolling slats are used. If a substantial blind is desired, the fixed slats should always be used; the light passing blinds opened only two or three inches is very agreeable.

Fig. 26. Awning Blind Hinge in Use.

There is also on the market an *awning blind hinge.* This permits the blinds to swing in the usual way, and, in addition, to be clamped together; and with the tops against the house, the bottom can be set out from one to two feet like an awning (Fig. 26), giving a delightful soft light inside. But to accomplish all that is desired, it appears to be necessary to make these hinges delicate and light; and a little hard usage or a heavy wind will break them, so that the greatest care must always be exercised when operating these blinds, to leave them secure; and generally it may be said that such fixtures are unsuitable for wide or heavy blinds.

LOCKS

As has been stated, the hinge is the most important item of hardware from the standpoint of necessity or convenience; but it is apparently the general sentiment of both sellers and buyers, that the lock is the central figure. The manufacturer puts more thought on it than on any other appliance; and in selecting hardware, the customer generally devotes most of his attention to it. Perhaps the reason for this discrimination is that the lock symbolizes protection and defense; the term *symbolize* is here used because, on an analysis, the lock is rather a symbol than a real physical protection.

With the advancement in the art of lock-making, the knowledge of methods of nullifying the safeguard afforded by locks has also advanced, so that there are no locks to-day which cannot with more or less ease be operated by unauthorized persons. When elaborate and intricate locks are used, it is often ridiculous to see on what flimsy doors they are placed, and also what delicate and flimsy locks are placed on ponderous doors.

A brief study of the conditions usually surrounding the placing of locks will show the absurdity of expending large sums of money and of buying intricate locks with an idea of obtaining protection thereby. Under ordinary conditions, the moral effect of the lock is enough to afford protection; but when the experienced cracksman or determined burglar seeks to obtain entrance, neither moral effects nor mechanical appliances are a bar.

The object of the foregoing is to set forth the province which a lock should be considered as filling—or rather to show the province it does not fill—so that in buying this most expensive of hardware,

funds needed elsewhere may not be expended in intricate mechanism of doubtful protective value.

Locks are either of the *rim* type or of the *mortise* type. The rim lock is fastened on the face of the door (Fig. 27). It should be used only when protection is desired from the outside, as, for instance, on store or office entrance doors, and possibly outside house-doors. Locks of this type are usually operated by means of a key from the outside and a thumb-piece from the inside; if of a type requiring a key for both sides, they are no protection on the side on which they are visible, as the removal of one screw will usually allow of sufficient change of position of the lock to release the bolt Rim locks are not ornamental, are generally made of ordinary cast iron, and their use should be avoided in the better grades of work.

The mortise lock is set into the face of the door, so that only the face-plate, with bolt and latch, shows on the edge when open

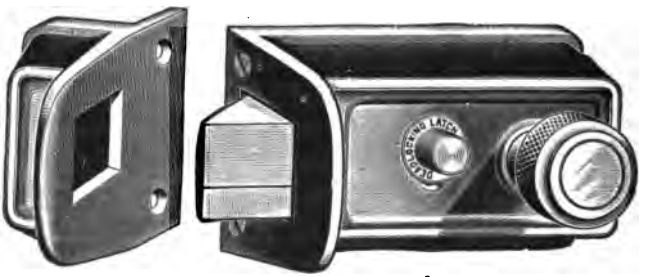


Fig. 27. Rim Lock or Night Latch
Courtesy of Sargent and Company, New Haven, Connecticut

(Fig. 28). Inasmuch as it is necessary to cut out the woodwork of the door to place a lock of this type, the smallest and thinnest lock which will serve the purpose should be chosen.

As all the parts except the face-plate are hidden in the mortise, there is no use in ornamental work. The exposed face is usually plain brass or bronze; the case is generally cast iron or pressed steel, which should be heavy enough to hold its shape firmly, without springing or cracking if for any reason the mortise for which it is intended is not of the proper shape or size, which it rarely is.

After the question as to the use of a rim or a mortise lock is settled, another, covering just what is wanted of each lock, should be carefully considered, so that appliances will not be installed which are never to be used. Practically all locks contain a *latch*—that is,

the part which is operated by the knobs and which holds the door closed under ordinary conditions. As the latch is the part subject to most frequent use, it is very desirable that its mechanism be as simple as possible and that all moving parts be of brass or bronze. The use of iron, except in the casing, should be avoided.

It is often observed, in finished work, that the latch is not easily pushed back when the door is shut, making it necessary to turn the knob or to give more than an ordinary slam to latch the door. This is caused by badly fitting parts, poor springs, and the shape of the latch-face. The straight bevel type shown in Fig. 29 is considered the best and develops the least friction. The type of latch-face shown in Fig. 30 is satisfactory but is not considered quite as good as Fig. 29.

Fig. 28. Mortise Lock
Courtesy of Sargent and Company, New Haven, Connecticut

The latch should be heavy. It receives hard usage, and the heavier it is, the more evenly it responds to pressure. There are various *anti-friction* devices on the market, but they are rarely any improvement over the well-designed and well-manufactured latch-face. Should the selection, however, be unfortunate, and the operation of the latch unsatisfactory, conditions can be remedied to a certain extent by occasionally oiling the face of the strike with a heavy oil which will not readily disappear.

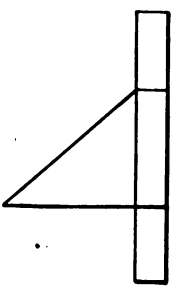


Fig. 29. Best Type of Outline for Latch-Face

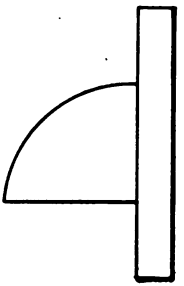


Fig. 30. Satisfactory Outline for Latch-Face

In a large majority of cases, this latch (Fig. 28) will perform all the necessary functions of the lock and latch for outside doors if it is arranged with *stopwork* on the face. By pushing in one button, it can be operated from the outside only by means of a key; by reversing the button, it becomes a latch operated by knobs from both sides. Under the former condition it is as secure a lock as is the *dead bolt* operated by a key independent of the latch—a device which, while often considered a necessity for outside doors, is rarely used.

Fig. 31. Cylinder Type of Latch-Key

Inside doors rarely require a lock; and where they are not really needed, it is not wise to arrange for a possible future need, since in most cases, if such need arises, the keys will either have been lost or have become hopelessly mixed.

In selecting door locks, the first and most important consideration should be given to the latch lock. A type with the heaviest mechanism and best materials in the smallest case, should be selected; and that type, in one of its various forms, should be used throughout to the exclusion of all other forms, unless unusual conditions require other appliances—as, for example, where doors are to be locked from both sides, in which case the dead bolt is necessary, which can be operated only by key from either side. With this, as with all hardware, the simplest form is the best. However, locks with peculiar combinations, such as turning the key in a certain way to operate one bolt, and further in the same way or in an opposite direction to operate the second bolt, are popular; and while they afford no additional protection, they are being manufactured in increasing quantities. The distance between the center of the knob and the face of the lock should never be less than $2\frac{3}{4}$ inches, and it is better to be 3 inches. If less, the fingers of

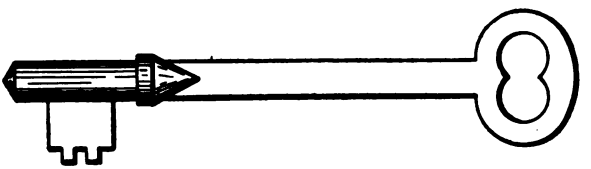


Fig. 32. Common Type of Bit Key.

the operator will be pinched between the knob and the door-frame.

The key is an important item, and selection of the style of key should always be with strict reference to the use of the lock. The *latch-key* will be in daily use and carried by several persons, and should be of the smallest *flat-key* type (Fig. 31), with a distinctively shaped hand end so that it can readily be distinguished at all times from desk or drawer keys on the same ring.

If a dead bolt is used, its key should be of the larger type of *bit key* (Fig. 32). This is inconvenient to carry away, is not easily lost, and can generally be found at the rare intervals when it is needed.

All keys should be strong, whether flat or bit. Delicate keys are often twisted off when the lock "sticks" a trifle, or—which happens more frequently—when they are not inserted quite far enough before an impatient wrench is given them. Once bent, they are useless. They should be well finished and nickel-plated. Otherwise they will rapidly wear the pocket, and become rusted; and a rusty key will rarely work satisfactorily.

It is often desired that locks be master-keyed—that is, so constructed that each lock will be operated by a key differing from any other, but also so made that one *master key* can open all, as in the case of office buildings, for janitors' use, and in hotels to accommodate the service. This requirement is always unfortunate, as it permits the passage of every lock in the series by one key. This is like very securely guarding several entrances to an enclosure and leaving one gate with but little protection; and it is much better to cause the janitor a little additional trouble by requiring him to carry a separate key for each lock. If the master key is lost, the only remedy is to change the entire line of locks.

There should be no identifying marks on keys or rings indicating the location of the locks they will operate, for, in case of loss, the finder would thus be enabled to use them.

In selecting locks for any particular building, a careful diagram or floor-plan should be prepared, on which the swing of all doors is indicated and each door numbered (see Fig. 33). A *right-hand* (R. H.) door is one which when opened away from a person has its butts on the right-hand jamb; and a *left-hand* (L. H.) door has its butts on the left-hand jamb. All latches are either R. H. or L. H.

while many types are made so that by reversing some of the mechanism they can be changed from R. H. to L. H. It is better to get an unchangeable latch, which is less complicated in its mechanism and will work easier and last longer than one with interchangeable parts.

The doors on which it is intended to place locks with pass keys (Fig. 34)—such as front and back outside doors—should be indicated; as should also those doors it is desired to lock on the inside by key (as pantry or closet doors, Fig. 35), those it is desired to bolt (as bedroom doors, Fig. 36), those requiring simple latches without

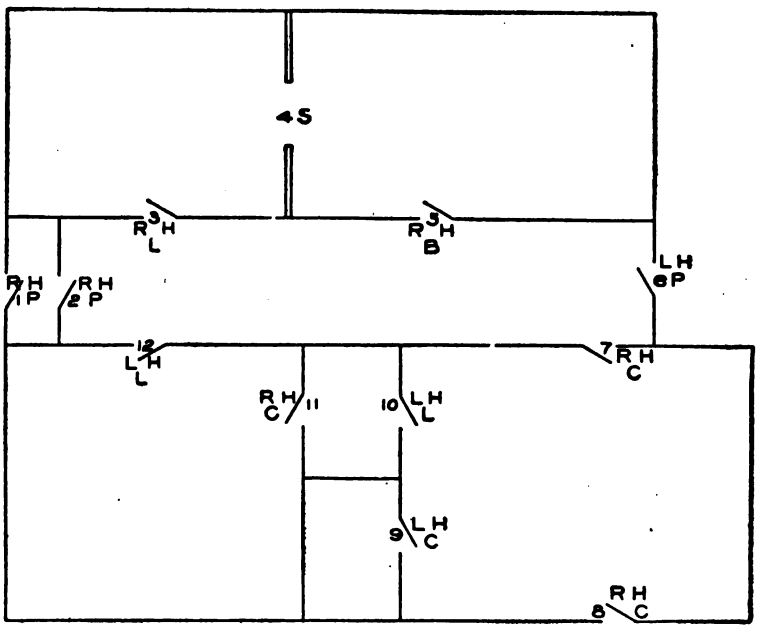


Fig. 33. Typical Floor-Plan Showing Location and Swing of Doors.

lock or bolt (as doors from hall to dining room, Fig. 37), and sliding doors, which require an entirely different type of lock (Fig. 38). A bill can be made somewhat on this line:

2	Right-hand locks with pass keys, marked	R. H.-P	Nos. 1–2,
1	Left " " " " " "	L. H.-P	" 6,
1	Right " latch "	R. H.-L	" 3,
2	Left " latches "	L. H.-L	" 12, 10
1	Sliding-door latch "	S	" 4,
1	Right hand " with thumb-bolt, "	R. H.-B	No. 5,
3	" " " " key "	R. H.-C	" 7, 11, 8,
1	Left " " " " "	L. H.-C	" 9,
12	Total locks and latches.		

Fig. 34. Lock with Pass Key

Fig. 35. Latch with Key-Bolt

Fig. 36. Latch with Thumb-Bolt

Fig. 37. Simple Latch

Upon receiving the locks and latches, there should be attached to each a tag bearing the number of the door for which it is intended. If the fixtures are not numbered and it is left for the fitter to sort them out as he proceeds, there will be confusion before half the items are in place.

Aside from the door locks above referred to, there are almost numberless uses to which locks are placed in minor situations; but it is safe to say that not over 10 per cent of locks in such minor situations are ever used—as, for example, on the cupboard door, bureau drawers, etc., which, though always having locks, are rarely locked. It is always better to omit a lock where there is no actual necessity therefor, and when the necessity occurs, to get a lock of the best type. A lock operated by a flat key is usually safe for such places; those with the old bit key are rarely of any protective value.

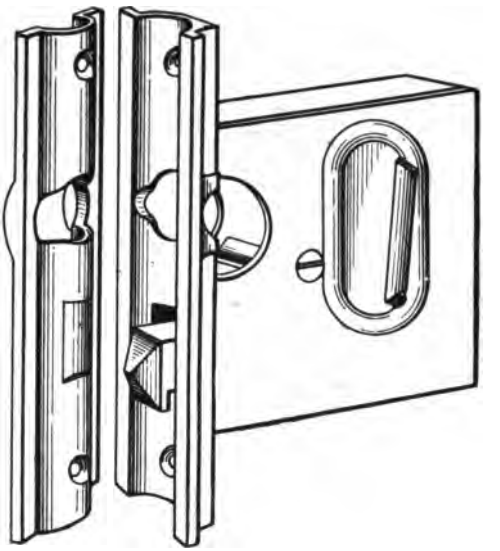


Fig. 38. Sliding-Door Latch.

KNOBS AND ESCUTCHEONS

These are parts in which the vanity of the owner can be—and often is—displayed. The *escutcheon* is the plate through which the key-hole is cut. It is usually combined with that on which the knob is placed, and is the lineal descendant of the escutcheon of chivalry borne by knights and persons of distinction. Careful study of escutcheons on the doors of houses, will show that much of the character of the owner is still indicated thereby.

With this fact in mind in the selection of hardware, special attention should be given this feature. A plain brass or bronze plate and knob is usually a safe selection; but even then such items as its thickness or the way the edge is finished tell of conditions governing

its selection. When the design calls for something more elaborate, it is a mistake to be confined to simple, plain work; but under no circumstances should a knob and escutcheon of elaborate or ornamental character be selected simply on account of such character when the surroundings do not call for display.

The escutcheon, at the point where it receives the shank of the knob, should always, even in cheap work, be so enlarged that it will project over the shank of the knob at least a quarter of an inch and fit closely; this stays the knob and gives it a firmness when gripped not otherwise obtained. The escutcheon plate should also be long enough to extend both above and below the lock; if it does not do so, the screws that fasten it in place can rarely be long enough to hold it firmly, as the side of the lock is usually within $\frac{3}{8}$ or $\frac{1}{2}$ inch from the surface of the door. The screws securing an escutcheon should always extend one inch into the wood.

A great variety of materials are used for both knobs and escutcheons—wood, glass, iron, brass, bronze, and metal plated with silver or even gold—and designers have produced many very artistic as well as many very much over-elaborated forms, which are easily cast in metal—sometimes with unfortunate ease, as it permits the reproduction of designs cheaply and has therefore encouraged their use in many cases where it would have been better to omit a large part of the ornamentation. This cast ornament is an American feature of hardware, that produced in Germany, France, or England being more generally of the wrought type, artisans in those countries being skilled beyond the American in forged work.

The *knobs*, and the *spindle* that connects them—which together operate the latch—are primarily mechanical contrivances. and should be considered as such. The old scheme of making a solid spindle which was secured to both knobs by screws through the shank of the knob running into the nearest hole in the spindle, the play being taken up with thin washers, was always bad, inasmuch as, when enough washers were put in to make the knob feel solid and to prevent its rattling, it was usually so tight as to bind. The screw always works loose, and being small is lost as soon as it drops out. Before a new screw is found, some of the washers very likely disappear; and if new ones are not obtained, the knob remains permanently loose.

Many devices have been provided to do away with these defects

in mechanism. In one of these devices, the spindle end is in three pieces, the middle one wedge-shaped. A screw through the shank bears on this wedge-shaped piece, thus expanding the two others

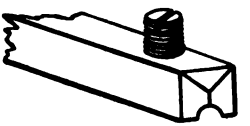


Fig. 39. End of Expanding Spindle.

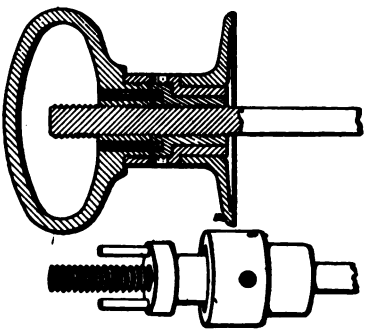


Fig. 40. Knob-Holding Device, Adjusted by a Thread.

against the sides of the slot in the shank (see Fig. 39). In practice it is found that this screw when set hard against the wedge does not work loose; before it is set, the knob can be most delicately adjusted without washers; and if the screw should work loose, notice would at once be given by the slipping of the knob before the screw was lost.

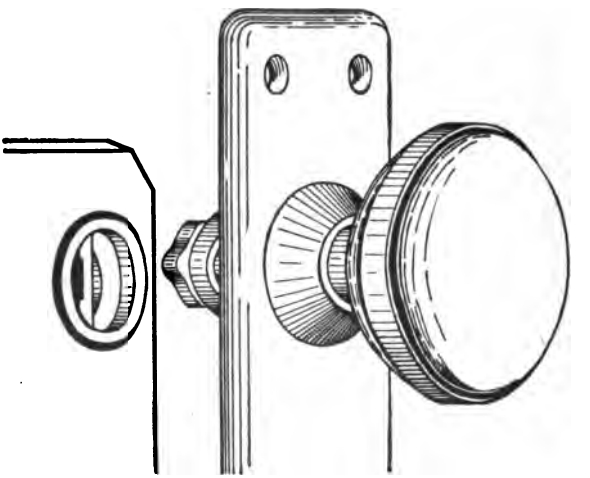


Fig. 41. Knob-Holding Device without Spindle. (Obsolete)

Another but somewhat more expensive device is that illustrated in Fig. 40, in which the knob can be delicately adjusted by a thread so that an exact fit can be obtained.

The device shown in Fig. 41, in which the spindle is entirely dispensed with, and the knobs are slipped into the lock-case independently of each other, are no longer on the market.

Where locks with pass keys are used so that stopwork changes the latch into a lock, it is desirable that one side only should be affected. The spindles of such locks are, therefore, jointed in the lock with a swivel-connection which allows at all times a free movement of the inside knob or key (see Fig. 42).

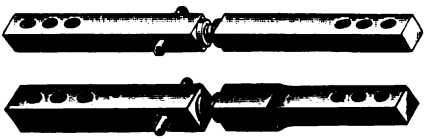


Fig. 42. Two Different Types of Spindles

Door knobs should be from $6\frac{1}{2}$ to 7 inches in circumference, whether round or oval, to be gripped with ease; if larger, they should accompany locks which allow them to stand far enough out from the finish to prevent the hand from being pinched or bruised in turning the knob or opening the door. This distance, for ordinary knobs, is given under *Locks* as $2\frac{3}{4}$ to 3 inches, which distance should be increased if a larger knob than ordinary is used. A perfectly plain knob is rarely out of place, while any attempt at ornament is more than likely to appear so. For ordinary work, *spun brass* knobs wrought from thin sheet metal (Fig. 43) are very serviceable, and have the appearance of the genuine cast metal. With the plated butts, they make a good combination (though they will not stand blows without indentation), and for most purposes are as serviceable as the cast metal. In better work, however, the cast brass or bronze should preferably be used, in which the metal is cast from $\frac{1}{8}$ to $\frac{3}{16}$ inch thick; these are the strongest type used.

Fig. 43. Spun Brass Knob.

For the last few years there has been a tendency to adopt the types of Colonial days, and nowhere is this tendency seen more than in hardware. And with these designs have come some of the olden appliances, the most prominent of which are latches and knockers. The former are most useful, and, when applied in proper locations,

have a charm which knobs do not possess; but in the case of mortised fixtures of the type usually operated by knobs, they are frequently—in fact, generally—out of place.

Knockers as now used are only for ornament, being rarely used by callers for summoning the inmates of the house.

SASH HARDWARE

In all the range of house hardware, there is none so unsatisfactory as that used in connection with window-sashes. This is not altogether the fault of the hardware, as the customs regulating the manufacture of the sashes themselves make them the most flimsy part of house construction. The glass is wide, and the meeting rails narrow. Sooner or later someone tries to force up the lower sash when "stuck," by pushing violently on its top rail, or tries to pull down the top sash by pulling on its bottom rail; these operations pull the rails away from the glass, and if, when "fitted," there was not considerable play, the sashes never come together again. Any sash-lock adapted to such a position must necessarily be far from exact in its working. All work perfectly in the model; few work at all on the real sash. Therefore, in selecting this fixture, it is wise to pick out the strongest which will allow for variation in the rails, and, before purchasing, to visit some house in which they have them installed, in order to see how they operate. Even after this trouble, difficulties will be experienced. Most of the locks are safe, at least, little attention need be paid to representations that certain kinds can be opened by means of a thin blade inserted between the sashes from the oustide; for, after one has seen the difficulty of working them from the inside by the usual means, he will never be troubled by the thought of anyone working them from the outside with a putty-knife.

There are certain kinds which throw up the arm against the glass of the upper sash when unlocked. This kind should not be used, as they at once give notice to anyone outside, if the window has been left unlocked.

Window pulls or *handles* on the lower sash are always very difficult things to get a "purchase" on with the ends of one's fingers when the sash "sticks;" and while the socket in the top sash with a pole and hook to move it, is a trifle the most exasperating of any part

of window hardware, manufacturers have as yet failed to remedy the trouble.

There are on the market quite a large number of complicated devices for operating sashes, either swinging them into the room or sliding them up and down; but in practice the old trouble of flimsy sash construction makes such devices of no more value than those of the old form. It is doubtful whether any remedy will be found until custom requires the use of smaller glass, of sash bars to stiffen the sash, and of better carpentry work in fitting, and requires owners to keep all parts of sashes and frames thoroughly oiled to prevent the constant absorption of dampness, thus preventing swelling and shrinking with their concomitant effects of sticking and rattling.

When sashes are hung at the side—as is frequently the case—they should swing outward; if they swing inward it is difficult to keep out storm water. For holding them at any required angle, bars are

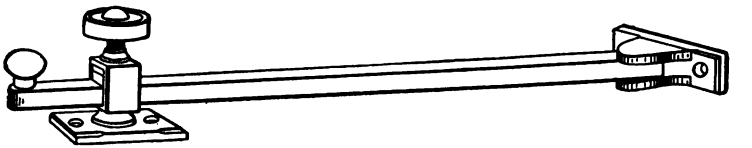


Fig. 44. Typical Casement Adjuster

made with clamp screws (Fig. 44). These work very satisfactorily; but, unless great care is exercised to leave the sash always firmly clamped, sudden wind may wreck the sash and glass, leaving no protection from the storm. As a general thing, accordingly, it is better to retain the old sliding type of window, especially since, with swinging windows, the use of outside blinds is impossible.

The *sash-pulley* (Fig. 45) is out of sight, and often almost anything in the way of material and make is considered good enough. This particular piece of hardware, however, receives so much wear, and is capable of wearing out so much good window-cord, that, if the future is to be reckoned with, care should be taken in its selection. First of all, the wheel should be as large as possible, as the constant crimping of the sash-cord over a wheel of short radius rapidly destroys the fibre, so that after giving great annoyance for a time by becoming caught in the wheel, the cord finally breaks and lets the weight drop to the bottom of the pocket.

For plate-glass windows or wide, heavy sash, chains are generally employed. They are composed of links which follow the curve of the wheel (Fig. 46), and are not easily worn out. The groove in

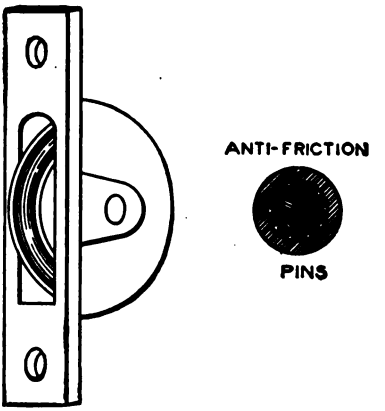


Fig. 45. Sash Pulley.

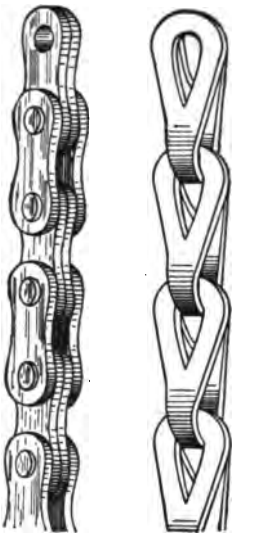


Fig. 46. Sash Chains.

the wheel should be square to conform to the lines of the chain, and not as for cord (see Fig. 47).

The pocket in which the window weight runs, should never be less than two inches in depth (crosswise), nor the pulley-style less than $\frac{7}{8}$ of an inch thick. Thus it will be evident that to allow the weight to hang in the middle of the box, the wheel of the pulley must be not less than two inches in diameter *on its running face;* that is, the diameter of the wheel should always be equal to the thickness of the pulley-style *plus* one-half the depth of the box, as shown in the sectional diagram, Fig. 48. This arrangement gives the minimum friction and insures easy running. If a smaller wheel is used, not only is the cord rapidly destroyed by the constant crimping, but the weight "drags" on the back of the pulley-style, making the operation of the sash difficult and noisy.

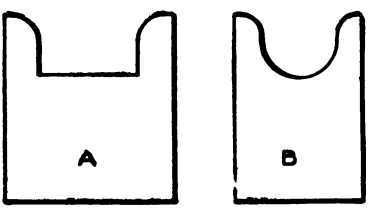


Fig. 47. Sections of Sash Pulley Rims—A, for Chain; B, for Cord.

Pulley wheels are generally measured by manufacturers and dealers, to the outside of the flanges, so that a wheel two inches on

the running face is often styled a 2½-inch wheel. The money invested in such a wheel is gained many times over in saving the annoyance and expense of broken sash-cord.

If the pulley is steel-bushed and has roller bearings, it will be better in the long run, and these items add little to the expense. The running face of the wheel should be smooth; and all parts may be of iron, without detriment to the appearance or the usefulness of the fixture. A plain brass or bronze face and wheel are to be preferred, however, if the small additional expense is not a bar.

The pulleys usually put in stock frames are 1½-inch iron pulleys costing about 50 cents a dozen; and 10 cents a dozen is usually added for each additional quarter-inch in the diameter of the wheel, though the mill man will often want a little extra for making the frame "special" in case the larger wheel is used. The brass wheel with roller bearings and brass face will cost about three times the above price—or, possibly, 50 cents extra for each window.

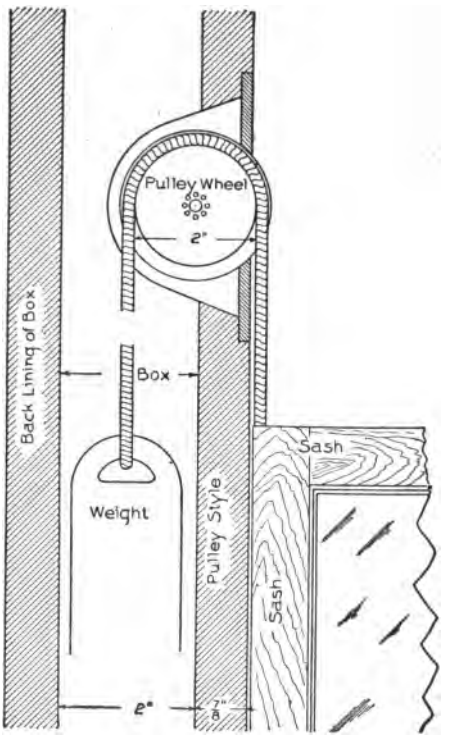


Fig. 48. Section of Pulley and Pulley-Style; Showing also Sash and Weight.

There are on the market very useful pulleys over which the sash-cord can be carried to boxes several feet away (Fig. 49). Pulleys of this type can be used where the mullions between windows are too small to carry the weights. These pulleys dispense with the necessity for lead weights, which are expensive and are usually crowded into boxes so small that they work unsatisfactorily. By the use of combinations of these pulleys, the cord can be carried an indefinite distance to a box capable of receiving a large iron weight, and

the width of the mullion can be reduced to the minimum thickness.

Sash-cord is a very important item, and braided cotton cord is probably the cheapest in the long run. It is better to get a *small* rather than a large size. The wearing of the cord is due to the fact that in passing over the pulley the inside or the part against the wheel is compressed or crimped, while the opposite side is stretched, thus producing a constant wear and strain of the fibre of the cord, which finally breaks it down. It will be evident that this disintegrating action will increase with the larger diameter of the cord. A cord just large enough to hold the weight safely, is the best. A simple test is to suspend four of the heaviest weights to be used, by one cord; if it will hold them, it is sufficient size to carry the one weight.

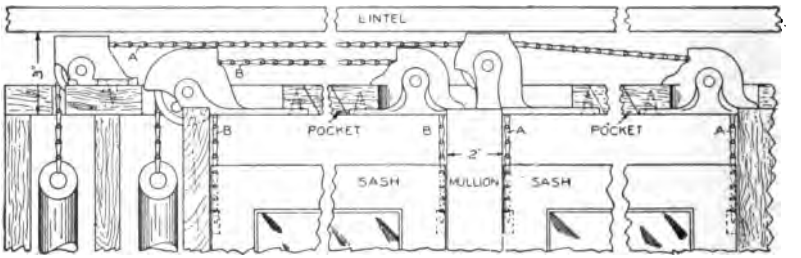


Fig. 49. Pulley Arrangement for Carrying Sash Cord to Distant Boxes.

Taken as a whole, the window—with its lock which rarely works, its exasperating pulls, and its sash-cord broken when most needed—is one of the oldest, and still one of the greatest, of modern inconveniences. Undoubtedly the first step necessary to make the window more satisfactory, it to make the sash narrower and cut the glass smaller, with substantial muntins, so that the sash will be firm. This, with a little better workmanship on the frames, will, with present appliances, make a very satisfactory window.

MISCELLANEOUS HARDWARE

Bolts. The bolt is one of the oldest and simplest contrivances for securing different parts in a desired position, and is still a most necessary item of hardware. Here, weight of metal counts for as much as, if not for more than, in most other items of hardware. This weight should be balanced in the different parts to insure strength

of the whole. A heavy moving rod, for example, in some bolts, is made to engage with a thin keeper-strap attached to the base by very slight tenons headed over, so that, while it is probable that it would take 2,000 pounds pressure to break the rod, a pressure of 100 pounds might be sufficient to force the keeper-strap from its base (see Fig. 50). Inasmuch as a bolt cannot be *picked* like a lock, its value lies in its strength to resist force, and this should always be remembered in its selection.

As a general rule, all bolts operated by a sunken thumb-piece (Fig. 51) should be avoided, for, if they "stick"—and they generally do—very little power can be exerted by the end of a thumb. There are many lever and knob devices which permit the direct application of a considerable power. Two forms of these devices are shown in Figs. 52 and 53. This point should receive attention in selecting bolts for the standing leaf of a double door, or for cupboard doors.

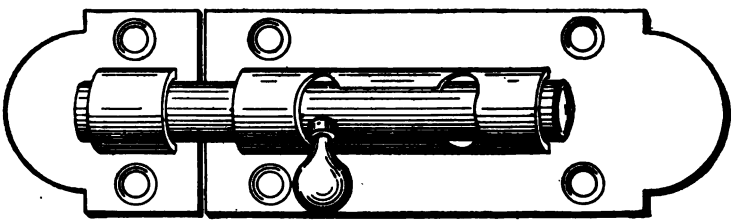


Fig. 50. Common Type of Bolt with Keeper-Strap.

The rod on a bolt should be tapered at the end, as the two parts rarely come exactly together so as to permit the rod to enter the keepers; if it tapers, it will, as it enters, draw the door to its proper position.

For *drop-front drawers* in linen closets, it is necessary, in order to save space, to use *flush hardware*—that is, hardware which does not project beyond the drawer front, which should be just inside the closet door. Fig. 54 illustrates a *flush-ring cupboard catch*, which will serve the purpose; it is of the type usually seen on store show-case doors; in fact, such doors throughout are good examples of the arrangement of drop-front drawers. A large size of fixture should always be chosen. Stay-chains should be put on each end of these fronts, to prevent them dropping below a horizontal position, in order both to prevent straining the hinge and to provide a strong extension to the drawer when open, whereon to lay linen.

In place of a bolt, to secure the standing leaf of a cupboard door, a *knee-catch* (or elbow) is often used (Fig. 55). This is more conveniently operated than a bolt, requiring no action other than shutting the door to catch, and a simple motion to open. The largest size of this fixture should always be used.

Chain bolts (Fig. 56), are most useful in allowing the door to be opened a few inches, and yet locking it with a partial security. They

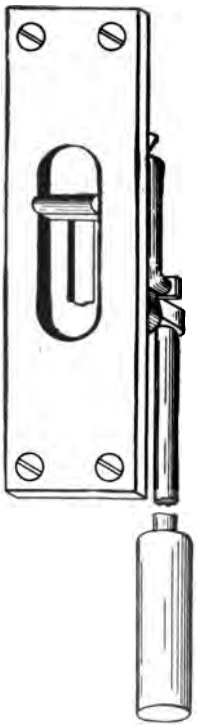


Fig. 51. Bolt with Sunken Thumb-Piece.

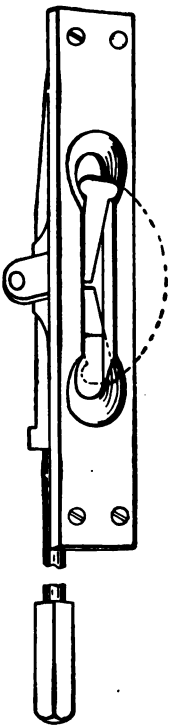


Fig. 52. Lever Bolt.

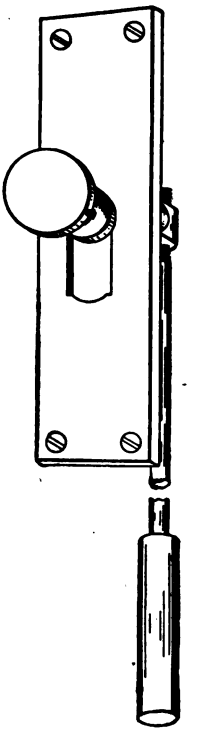


Fig. 53. Knob Bolt.

are often used to permit ventilation, or to allow the inmate to learn the character of a caller before fully opening the door.

The ice-box door of the north piazza (see Fig. 69) needs special attention, as a slight crack will allow the warm air to reach and meet the ice. A clamp which will force the door into its frame, must be used. Fig. 57 shows a good, strong form of such a clamp; ordinary strong hinges are suitable for the door.

Door Checks and Springs. These items are referred to under the heading *Butts*. A door check and spring consists of a very strong spring applied to close the door suddenly, and, in connection with it,

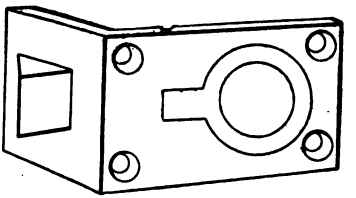


Fig. 54. Flush-Ring Cupboard Catch

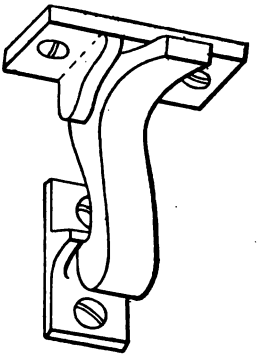


Fig. 55. Knee-Catch

a cylinder in which a piston runs freely until the door is nearly closed, when either the air or some oil or other liquid which cannot be frozen in the cylinder checks the rapid piston action, so that the door is closed easily and without a slam (see Fig. 58). These checks cost in place from $4.00 for light doors, to $7.00 for those of heavy type. They are fastened on the top of the door, and are no disfigurement. The type shown

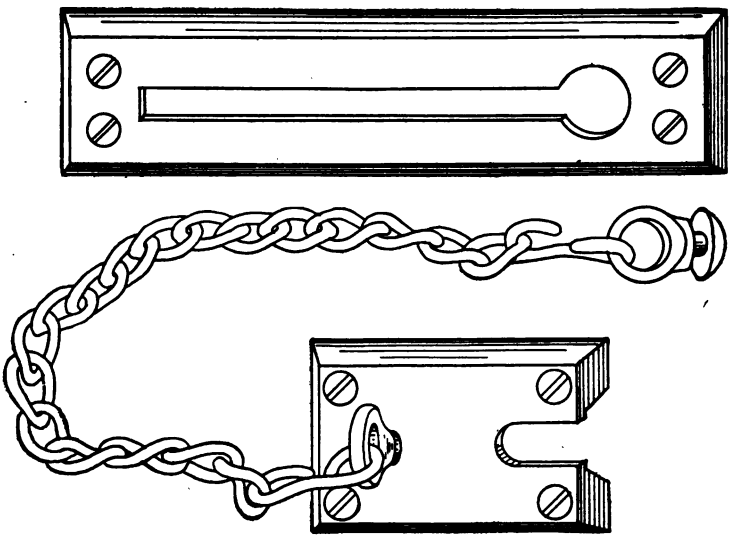


Fig. 56. Chain Bolt, Allowing Door to Be Partially Opened

in Fig. 58 uses a liquid in the cylinder and represents one of the most reliable designs. By means of a screw at the end of the

cylinder, the action of the liquid can be regulated. These door checks are made in a great variety of styles and on account of their durability and precision of action, they are very popular.

These springs are always in action, so that, if it is ever desired to leave the door open, some appliance may be used to accomplish this purpose. As they do not generally permit the doors to swing back against the wall where hooks could be used, *foot-bolts* are placed

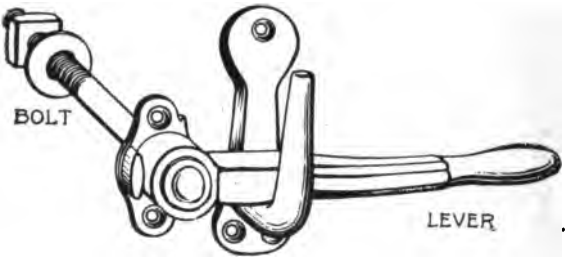


Fig. 57. Refrigerator Clamp

on the bottom rail; these have a flat top which can be pressed by the foot into a slot in the floor.

There are also on the market a great variety of patented bolts, most of which operate by means of a spring actuated by the foot. The type shown in Fig. 59 is of exceedingly simple construction. By placing the foot upon the roughened plate at the top of the piston rod a spring is compressed so as to force the rubber end-piece against the floor. A ratchet holds the spring in tension until the release plate at the top of the cylinder is touched by the foot, when the plunger springs back and relieves the tension. These door-holders are very positive in their action and will hold heavy or light doors in any position desired. Another but much simpler type of holder is shown in Fig. 60. The short rod is rubber tipped and can be swung down to the floor as described. When not in use, the rod is pushed up with the foot, the notch at the joint fitting a little plunger held by

Fig. 58. Door Check and Spring
Courtesy of Sargent and Company, New Haven, Connecticut

a spring in the base plate, so that the rod is held up against the door until used.

Kick plates and push plates, while not often needed in house hardware—except, possibly, for double-acting doors—are plates of metal not less than $\frac{1}{16}$ inch thick screwed onto the face of the door to protect it from wear. The kick plate, as its name implies, is the plate put on the bottom rail where persons are likely to apply the foot in kicking the door open. In public buildings, such plates are often put on for ornament; and also, where the surrounding finish is of marble, these plates protect the finish of the doors from the soap and often acid, used in cleaning the floor and base marble. It is needless to say that for such uses, the perfectly plain plate is alone appropriate.

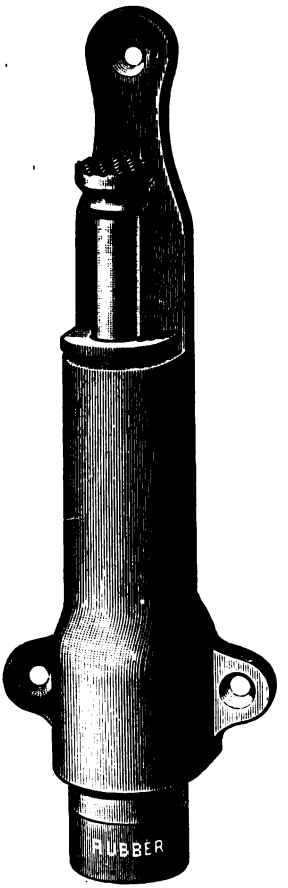


Fig. 59. Sargent Door-Holder Actuated by Spring Operated by Foot

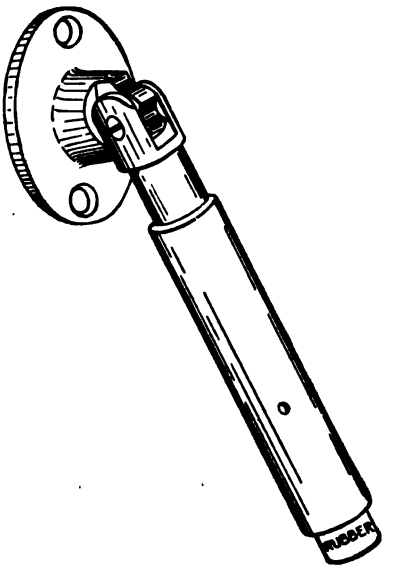


Fig. 60. Another Type of Door-Holder

Push plates are used to protect the finish of doors where persons push them open with the hand. If they are not used, the finish on the doors soon shows where the pressure is applied, and later it will be completely worn off.

Neither kick plates nor push plates should be used except where there is a necessity therefor; they are not properly subjects for ornamental treatment; and they add materially to the weight of the door, which in its lightest form is a severe strain on the butts. The plain face of the metal shows any indentations, and it is difficult to keep bright. Careless cleaners, moreover, are apt to rub off the finish of the wood, so that the plates become surrounded by an unsightly fringe of unfinished wood.

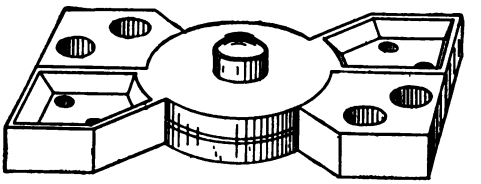


Fig. 61. Transom Fixture for Vertical Pivoting.

Sliding-Door Sheaves. In many places it is desirable to have the door slide back into pockets in the partitions. There are on the market many devices for trucks, generally good and inexpensive; but their installation and the framing incident thereto are matters of delicate workmanship, and if future trouble is to be avoided, it is well to see that appliances of this character are put in only by *mechanics* of known skill. After the doors are in and the partitions plastered, is a bad time to do the work over.

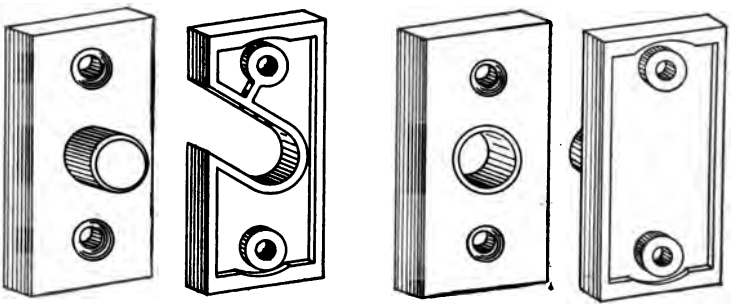


Fig. 62. Transom Fixtures for Horizontal Pivoting.

Transom Hardware. Transoms are generally hung from the top or bottom with fast-pin butts; or with pivots in the center of the top and bottom rail allowing them to swing at right angles with the transom bar, which is called *pivoting vertically* (Fig. 61), or with pivots in the center of each side to allow the sash to swing to a horizontal position, which is called *pivoting horizontally* (Fig. 62).

It is not necessary to refer to the butts here, except to say that

it will generally be more satisfactory to pivot the transoms than to hinge them, for, when hinged, it is necessary for the transom lifter to carry the full weight of the sash, which it very often fails to do satisfactorily; whereas, when pivoted, one side balances the other so that the lifter has nothing to do but overcome the friction of movement. These pivots are simple and easily applied.

There are on the market patented *friction pivots* of various types, which, while allowing the ordinary pivot action, hold the sash in any required position, thus doing away with the lifter. The transom, either pushed or pulled by an ordinary window pole-hook to the position desired, remains as left. To lock it in place, a large-size, heavy spring-ring catch is put in the top rail, which can be opened with the hook on the pole.

The transom lifter (Fig. 63) is an item in which little improvement has been made in the last generation. Its operation is generally unsatisfactory, and its use should be avoided if possible; but when it is necessary to use a lifter, it is advisable to get the heaviest rods, to prevent the unavoidable spring.

Fig. 63. Transom Lifter.

Cellar-Window Hardware. In this connection the hinging and locking of small cellar windows, above grade, may be considered. The sash are usually light; and it is not best to swing any portion out, as they are so near the ground that the portion turned out would be liable to damage. Also, it is often necessary to pass things through the window into the cellar, and this requires the full opening. The sash are particularly liable to shrinkage and swelling—more often the latter—which cause them to stick in the frame. Moreover, the cellar window is a favorite point for the burglar's entrance. It is

therefore usually necessary to hinge cellar windows with fast-pin butts *at the top,* to swing inward and up against the joists, and to have a strong handle for pulling them out of the frame when they stick, and a simple lock. Fig. 64 shows a simple but efficient device for fastening a cellar window. The screws in the part on the frame should be the longest obtainable; and the rivet or bolt holding the swinging part to the plate should be strongly secured, so that both points will resist any ordinary pressure from the outside. If a burglar brings his "jimmy," it is not likely that any appliance that can be used on the inside will resist its pry. For holding the window open, a strong wire hook and eye will be sufficient.

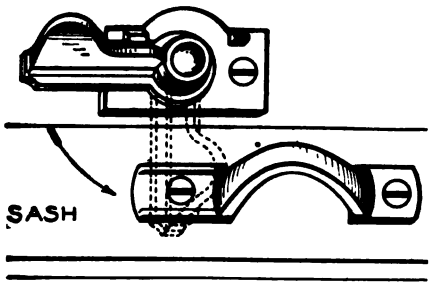


Fig. 64. Cellar-Window Fastener.

Wardrobe Hooks. In the selection and arrangement of wardrobe hooks, careful study will greatly increase the capacity of the usual *hanging space.* It is a mistake to select one type of hooks, and use that throughout; and also to consider that hanging space is confined to the walls. For ordinary items, common strong wire hooks (Fig. 65) can be used, set closely together; and if there is depth to the closet *flies* can be hinged so as almost to double the hanging capacity. In Fig. 66, *A A* represent the flies hinged on the wall. Arrangements of this kind, however, are not suitable for the hanging of garments which are required to retain certain shapes. For these articles, long horizontal hooks or pins (Fig. 67) should be provided; on these, certain garments can be hung close to the wall; while such items as coats can be placed on two, one in each arm, so that they will retain their shape and hang clear of the pieces against the wall.

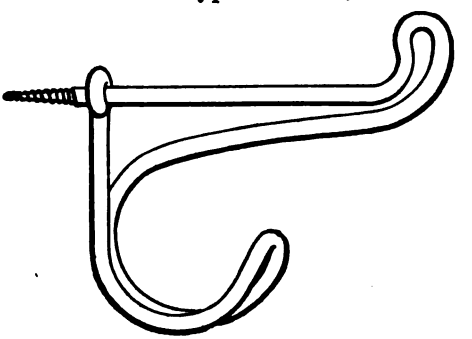


Fig. 65. Common Type of Wardrobe Hook Made from Wire.

In the more expensive materials, many special types of hooks are made for special purposes. They generally have a lower, minor hook, while the upper arm extends outward and upward for hanging hats; in other cases the upper arm extends out nearly horizontally, and then dips to support a garment clear of that below. A very useful article of furniture is a *tree* or *standard* (for use in bedrooms), to which are secured a large variety of hooks adapted to the various items of the wardrobe for daily use.

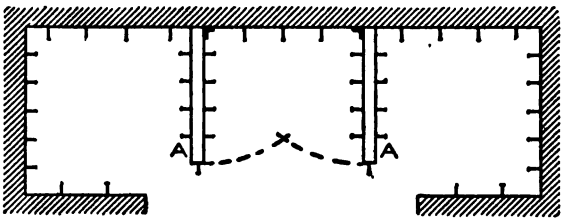


Fig. 66. Swinging Flies Hung in Closet to Economize Hanging Space.

FINISHES OF HARDWARE

It is necessary that hardware should have some special finish; and, as in the case of wood or marble or any other fine material, the object of the better finishes is to bring out and intensify the qualities of the material itself. Cheap hardware is generally japanned so as to present a smooth, shiny black surface; this is an excellent coat for wear and for protection against rust, and is not of objectionable appearance. Where ordinary unfinished hardware is used, it should be painted, varnished, or oiled at the same time the wood to which it is secured is finished. It is also well to paint the surface which presses against the wood; if this precaution is not taken, moisture may get behind, and resulting rust discolor the wood below.

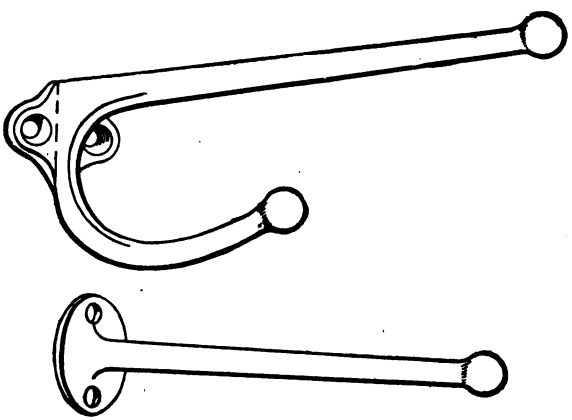


Fig. 67. Long Wardrobe Pins and Hooks.

Wrought Finish. Wrought iron, forged, is not often used except for specially designed work. When it is used, it should be finished under the hammer; that is, all the marks of the blows should be left, and no attempt made to file or smooth up the parts. The surface can be coated later with lacquer or some thin iron paint which will not obliterate the texture, in order to prevent rust; but under no circumstances should a coating in the nature of heavy lead and oil paint be used.

Cast Bronze and Cast Brass. These materials (the former being from 85 to 92 per cent copper, the balance tin and zinc; the latter from 60 to 70 per cent copper, the balance zinc and lead) are the most common finishes used in good hardware. They are sold at comparatively low prices, the finish being generally in the polished natural color, protected by a colorless lacquer. There are, however, many variations from this practice—such as strong greens—the results being produced by the action of chemicals artificially applied after all mechanical work is done. Some of these effects are very striking, but not suitable unless the surroundings are such as to call for such peculiar treatment.

Bower-Barff Process. This is perhaps the most successful of finishes for interior hardware. It is applied to either cast or wrought iron, and produces an intensely dense and deep black color free from gloss, over which no protective coating is needed. It, however, is expensive—equal in cost to solid cast bronze; and moreover, it is not so tough as brass or bronze, the process tending to make the metal brittle. This finish is not suitable for outdoor work in damp climates, where rust is apt sooner or later to attack it in such a way as to disintegrate the surface. While constant protection with lacquers might prevent or check this action, it is better practice, in exterior work, to use a finish adapted thereto.

Plating. As previously stated, this form of finish is used extensively in connection with butts, to make them correspond with the genuine brass or bronze used in knobs, etc., where plating would soon be worn off. For such purpose it is appropriate and enduring; but for exterior work, plating should not be used. Silver and gold plating are employed to a limited extent, but on account of the expense they are little used except in specially designed work.

SELECTING AND BUYING HARDWARE

There is no part of the building process in which the necessity for absolute *system* is greater than in selecting and making out a bill of Hardware. To illustrate this point, let us take the example of the Colonial House of which detailed plans are given in the article on "Estimating", Part II. It is surprising to find that there are required approximately 50 types, exclusive of nails, screws, bolts, etc.; and that there are 1,100 pieces of these various types required in this one building. Hardware is expensive *to buy*, and expensive to *put on*. If these eleven hundred pieces get mixed, a large amount of valuable time is consumed in getting them arranged; if too much is bought, the excess is a loss, as it is difficult to return broken lots; if not enough is purchased, the loss of time in going over the work again and again to find what is missing, is expensive; and waiting to have delivered the last belated portions of material still lacking, is exasperating.

Therefore the first thought should be to place the whole matter in such orderly shape that every point in connection with the selection, arrangement, and distribution is settled, and so clearly noted that future uncertainty relative to any point will be impossible. It is also necessary to determine the exact cost of the entire bill before deciding on any of the types; and only with a complete list is it possible to find just the relationship between the cheaper and better lines.

For all these reasons, a most useful purpose will be served if we now proceed to set forth in detail, step by step, a scheme for preparing bills of hardware, so arranging the items that definite and intelligent decision can be made, and serving also as a guide to the expeditious and accurate arrangement and distribution of the materials to the proper points for installation.

It is evident that the types at each point must be practically the same for all grades. Thus, for instance, a door requires butts (4 x 4 or 5 x 5 inches) irrespective of whether they are wrought-iron, japanned, bronze-plated, or solid cast bronze. Two knobs are required whether "Mineral" jet, wood, glass, or bronze is used. Therefore, in proceeding, the question of *quality* of material will generally be disregarded, except in cases such as knobs, where it is desirable to use a better material for the selected type in the major rooms and a cheaper material in the minor.

After the list is completed, it can be made out in three forms—the first designating the *cheapest* line appropriate; the second designating a line of *intermediate grade;* the third, the *best grade* which is suitable.

In preparing these three lines, there are many appliances which will not be varied. In the case of locks, for example, a thoroughly good grade should be used in the cheap line; there is no advantage to be gained in selecting expensive locks of the more intricate mechanism and more elaborate design, even for the better-grade schemes.

After these bills have been prepared, figures can be readily obtained on each, so that an intelligent decision based thereon can be made.

Listing the Items. The first step is to lay out the floor-plans, showing every point at which hardware is required (Figs. 68–71). Doors should be indicated with their swing *right-hand* (*R. H.*) or *left-hand* (*L. H.*). In the case of windows, it can generally be taken for granted that small cellar windows, unless otherwise indicated, are hinged at the top to swing up against the first-floor joists, and that all other windows, unless otherwise indicated, are *double-hung* with cord and weights. The location of china closets, pantries, linen rooms, etc., in which are cupboards, drawers, hooks, etc., should be clearly shown. These plans should be very simple, carrying no details except those necessary to indicate the need for hardware at the various points. It is better to make the drawings on tracing cloth or onion skin, so that after the hardware is designated thereon, prints can be taken for the use of the workmen.

On these skeleton drawings, every point requiring hardware should be numbered. Thus,

Basement Doors should begin with 1, 2, 3, etc.
" Windows should begin with 50, 51, 52, etc.
" Closets, cupboards, etc., should begin with 90, 91, 92, etc.
First-story Doors should begin with 101, 102, 103, etc.
" " Windows should begin with 150, 151, 152, etc.
" " Closets, cupboards, etc., should begin with 190, 191, 192, etc.
Second-story Doors should begin with 201, 202, 203, etc.
" " Windows should begin with 250, 251, 252, etc.
" " Closets, cupboards, etc., should begin with 290, 291, 292, etc., etc.

In this way the floor on which any number occurs can be recognized. Breaks in the numbering should be allowed, as it will be

found, in working out the later details, that certain points have been overlooked, and numbers can then be assigned which will not necessitate any rearrangement.

It will be noticed that in the above scheme of numbering, we have subdivided our hardware into three distinct lots—namely, for *doors*, for *windows*, and *miscellaneous items*. It is well throughout

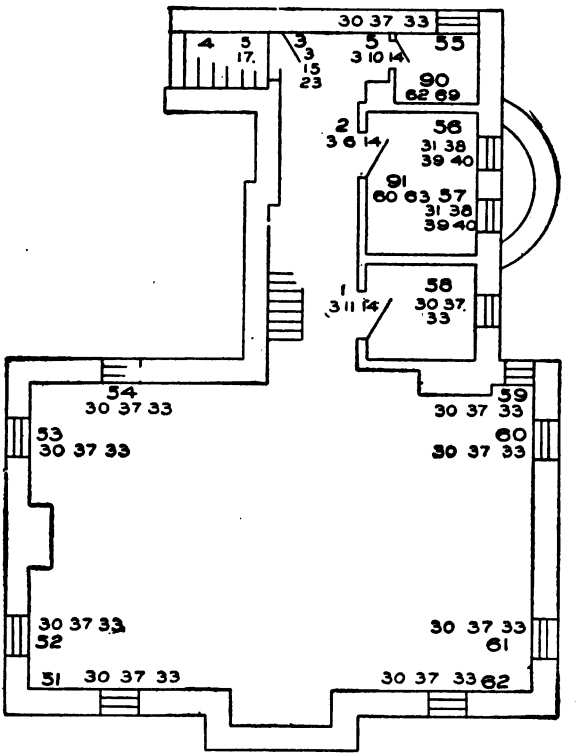


Fig. 68. Basement Plan with Hardware Items Indicated.

to keep these subdivisions entirely distinct, as in this way all liability to confusion will be practically avoided.

The second step is to make a list of appliances which will be required under the various divisions. Thus, under the heading *Doors*, we shall have

Butts of various sizes,
Locks " " kinds.
Etc. Etc.

Under the heading *Windows*, we shall have such items as

Pulleys,
Sash-locks,
Etc. Etc.

Under *Miscellaneous*, the list would include such items as

Hooks,
Drawer-pulls,
Etc. Etc.

Each item in this list should be numbered; and, to prevent confusion, designating letters should be attached, indicating the division

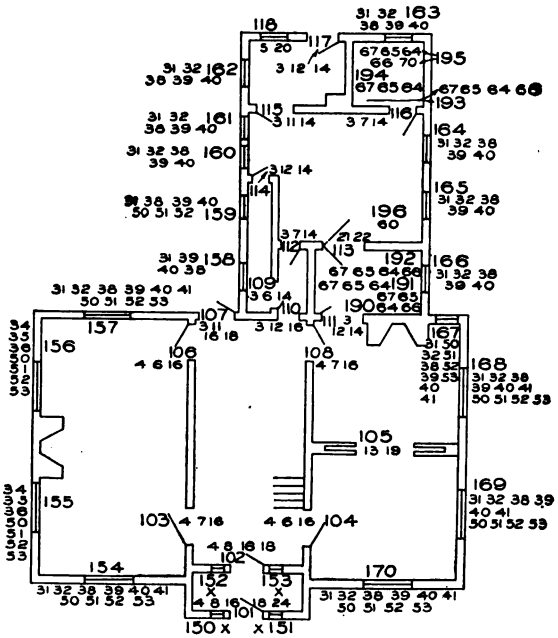


Fig. 69. First-Floor Plan, with Hardware Items Indicated.

to which it belongs. All numbers for door hardware, for example, should carry the letter *D*, as *D* 1, *D* 2, *D* 3, etc.; those for windows should carry the letter *W*, as *W* 50, *W* 51, *W* 52, etc.; and those for miscellaneous items should carry the letter *M*, as *M* 90, *M* 91, *M* 92, etc.

The third step consists in placing on the drawings, under each door, window, or miscellaneous item, the designating numbers of the hardware appliances required, so that it will be possible, by

merely referring to the plan, to ascertain just the hardware that will be required at each point. Several prints of these drawings should be made, as the successful placing of the hardware is dependent on following without deviation the lines thus laid down. The placing of a few items in wrong locations would produce confusion throughout the whole line.

The fourth step is to take three sheets of ordinary section paper ruled to quarter-inch squares each way, and to place on these sheets respectively, up and down at the left-hand edge, the layout numbers of the doors, windows, and miscellaneous items. (See Quantity

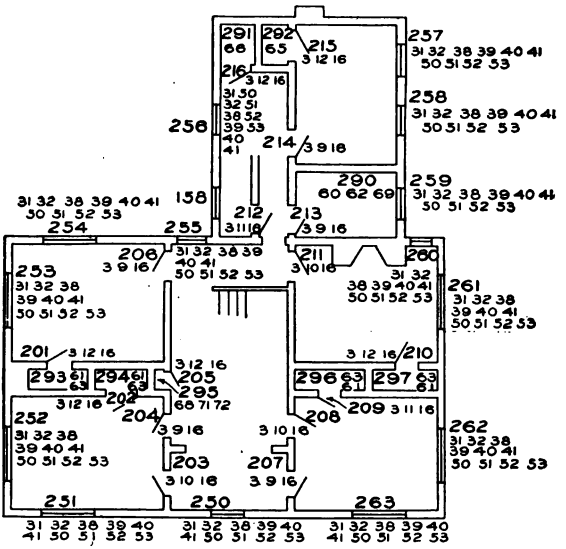


Fig. 70. Second-Floor Plan, with Hardware Items Indicated.

Sheets, pages 52-54.) Also, across the top of the sheets, place the designating numbers of the different items of hardware required under each division. Then, in the squares at the intersections of the lines running from the plan numbers and those dropping from the hardware numbers, note the quantity required.

There will be many occasions when for several doors or windows the same fixtures will be required. This condition is apt to breed carelessness, and mistakes are likely to occur for lack of *distinct consideration of each item.* If, through lack of care, three or four unnecessary appliances are included, their cost will more than offset the entire expense of making a careful bill in the first place.

As an example of how mistakes are liable to occur, note the window indicated between windows Nos. 255 and 256 in Fig. 70. This window, being on the stair, is shown in both the first and second story floors, and the hardware therefor was included in the first-story items. Unless distinct consideration is given to each item, it would be a natural mistake to double the order for this window; it would also be a natural mistake to include blind hardware for 158, 160, 161, and 162; but, by carefully examining the elevations, it is found that no blinds are required. Further, unless the detail sections through the pantry are studied, the arrangements for drawers, cupboard, flour-box are not understood.

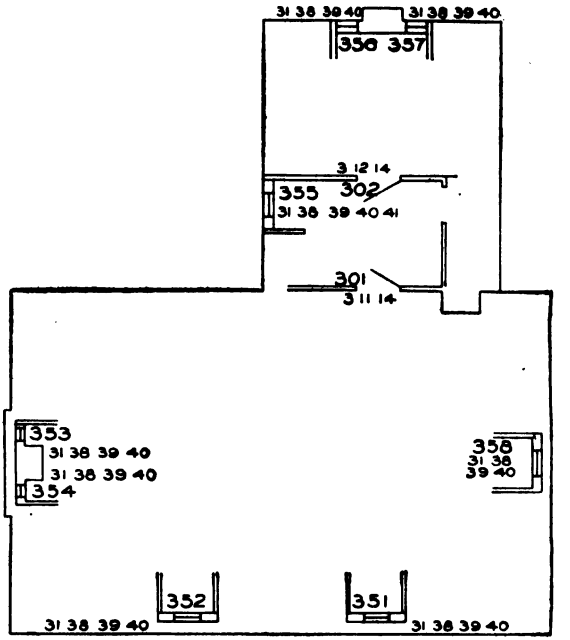


Fig. 71. Attic Plan, with Hardware Items Indicated.

The sheets are completed by adding the numbers in the vertical columns to obtain the exact number or quantity of each item required. The success of this entire scheme depends on absolute accuracy.

At this point is it very desirable that the results be *proven correct.* It is generally useless to go over the work a second or third time, following the original line, since the same mistakes are generally made each time. Some independent line, accordingly, should be selected,

in order to detect errors. A simple method is to add the number of appliances required for all points on the various plans, and then add the numbers on the sheet last prepared; if these sums agree, it is reasonably certain that no mistakes have been made.

For instance, counting the items required for doors throughout, we find we have as follows:

Basement	14 items
First Floor	55 "
Second Floor	48 "
Third "	6 "
Total....	123 items required for doors.

Adding up our quantity sheet, allowance has to be made when more than one of the items is used at one point. For instance three butts are required for each door, but they are noted on the plan as only one number.

We obtain the total of the items from the quantity sheet, as shown on page 52, as follows:

Under *D* 3, the total	93 ÷ 3 = 31 items.
" *D* 4, " "	18 ÷ 3 = 6 "
Item *D* 5, is doubled at one point, so that total	3 − 1 = 2 items
Items *D* 6 to *D* 21, inclusive	= 81 items.
D 22 is only one item on the plan	= 1 "
D 23 and *D* 24	= 2 "
Total	123 items.

In case the totals do not agree, add each floor on the quantity sheet so as to locate the discrepancy on one floor. When so located, it can be quickly found.

The fifth step is to incorporate the quantities now found in a bill or list which should distinctly state the character and quality of each, and include the requirement that all necessary screws shall be provided. In doing this, the separate items may be described in detail, or referred to under their *catalogue numbers* (if catalogues are at hand). Ordinarily, however, the most economical plan is to take the list to a dealer, and find what he can furnish the cheapest to meet each requirement.

CATALOGUES

It is entirely outside of the province of this paper to attempt to catalogue the hardware now made. There is no line of manufacture

in which the details are more intricate, and few retail or even wholesale stores carry a full line of any particular make. To persons interested in the purchase of hardware, it is suggested that upon request the manufacturers will forward catalogues showing their various lines; or such catalogues can be borrowed from a retail store. Any order for other than the commonplace, low-priced, stock hardware will generally be filled at the factory.

Any prices quoted in any textbook, can be taken only as a general guide; and it must be remembered that prices of hardware are especially liable to fluctuation. In busy times, it is often difficult to obtain a "bill of hardware" even at full market prices; whereas, when a slight easing off in business occurs, manufacturers and their agents not infrequently make material cuts in prices, in order to keep their shops full during the quiet season.

When work on any bill has reached this point, it is evident that the buyer can soon reach a decision as to whether it is necessary for him to buy a lower grade of hardware than he first intended, or whether he can afford a better.

Under the more common, slipshod way of buying hardware a man selects a few of the more prominent items without reckoning the cost of the numerous unlisted class, and is generally disappointed at the conclusion in two ways—first, in finding the number of items, and their expense, about double his first idea; and second, in finding that he has bought a lot of appliances not suited to his wants, costing as much as the items which were desired, but which his lack of forethought and system prevented him from getting.

Following the lines above laid down, our layout plans will appear somewhat as illustrated in Figs. 68 to 71; and our memoranda will have assumed a form something like the following:

Hardware for Doors

*D*3 Loose-pin japanned iron butts, with tip, 4 in. x 4 in
*D*4 " " " " " " " 5 in. x 5 in.
*D*5 Plain tee-hinges, 14 in.
*D*6 Knob-latches, *R. H.*
*D*7 " " *L. H.*
*D*8 " " stopwork and pass key, *R. H.*
*D*9 " " thumb-bolt.....*R. H.*
*D*10 " " " " .....*L. H.*

*D*11 Knob-latches, dead bolt .....*R.H.*
*D*12 " " " " .....*L.H.*
*D*13 Sliding-door latch.
*D*14 Mineral knobs.
*D*15 Iron store-door latch, with thumb-piece.
*D*16 Jet knobs.
*D*17 Padlock and hasp.
*D*18 Chain-bolt.
*D*19 Sliding-door hanger
*D*20 Refrigerator clamp.
*D*21 Double-acting butts
*D*22 Push-plates.
*D*23 Heavy iron bolt.
*D*24 Push button for electric bell.

Hardware for Windows

*W*30 Fast-pin plain iron butts, 3 in. x 3 in.
*W*31 Pulleys, 2 in. on running face
*W*32 Sash-lifts, Hook.
*W*33 Heavy cellar-window fastener
*W*34 Loose-pin butts, 5 in. x 5 in., same as *D* 4.
*W*35 French window latch, *L. H.*
*W*36 Extension bolt.
*W*37 Wire hook and eye.
*W*38 Sash lock.
*W*39 " cord.
*W*40 " weights.
*W*41 " sockets.
*W*42 " hook.
*W*50 Blind hinges.
*W*51 " hold-backs.
*W*52 " catches.
*W*53 " adjuster.

Miscellaneous Hardware

*M*60 Towel hooks.
*M*61 Coat hooks.
*M*62 Wardrobe hooks.
*M*63 Wire closet hooks.
*M*64 Knee-catches.
*M*65 Cupboard spring catches.
*M*66 Drawer-pulls.
*M*67 Loose-pin butts, with tips, 3 in. x 3 in.
*M*68 Fast-pin " no " 2 in. x 2 in.
*M*69 Toilet-paper holder.
*M*70 Pivot for flour-box (1 pair).
*M*71 Chain to hold drop-front drawers.
*M*72 Flush-ring cupboard catch.

Quantity Sheet, Door Hardware

	D 1	D 2	D 3	D 4	D 5	D 6	D 7	D 8	D 9	D 10	D 11	D 12	D 13	D 14	D 15	D 16	D 17	D 18	D 19	D 20	D 21	D 22	D 23	D 24
1	..	..	3	..	..	..	..	..	..	..	1	..	..	1	..	..	..	..	..	..	..	..	..	..
2	..	..	3	..	..	1	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..
3	..	..	3	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	1	..
4	..	..	..	..	2	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..
5	..	..	3	..	..	..	..	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..
101	..	..	..	3	..	..	..	1	..	..	..	..	..	..	..	1	..	1	..	..	..	..	..	1
102	..	..	..	3	..	..	..	1	..	..	..	..	..	..	..	1	..	1	..	..	..	..	..	..
103	..	..	..	3	..	..	1	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..
104	..	..	..	3	..	1	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..
105	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	1	..	..	..	..	..
106	..	..	..	3	..	1	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..
107	..	..	3	..	..	..	..	..	..	..	1	..	..	..	..	1	..	1	..	..	..	..	..	..
108	..	..	..	3	..	..	1	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..
109	..	..	3	..	..	1	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..
110	..	..	3	..	..	..	..	..	..	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..
111	..	..	3	..	..	..	..	..	..	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..
112	..	..	3	..	..	..	1	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..
113	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	2	..	..
114	..	..	3	..	..	..	..	..	..	..	..	1	..	1	..	..	..	..	..	..	..	..	..	..
115	..	..	3	..	..	..	..	..	..	..	1	..	..	1	..	..	..	..	..	..	..	..	..	..
116	..	..	3	..	..	..	1	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..
117	..	..	3	..	..	..	..	..	..	..	..	1	..	1	..	..	..	..	..	..	..	..	..	..
118	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	..
201	..	..	3	..	Pairs	..	..	..	..	..	..	1	..	..	..	1	..	..	..	..	Pair	..	..	..
202	..	..	3	..	..	..	..	..	..	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..
203	..	..	3	..	..	..	..	..	..	1	..	..	..	..	..	1	..	..	..	..	..	..	..	..
204	..	..	3	..	..	..	..	..	1	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..
205	..	..	3	..	..	..	..	..	..	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..
206	..	..	3	..	..	..	..	..	1	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..
207	..	..	3	..	..	..	..	..	1	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..
208	..	..	3	..	..	..	..	..	..	1	..	..	..	..	..	1	..	..	..	..	..	..	..	..
209	..	..	3	..	..	..	..	..	..	..	1	..	..	..	..	1	..	..	..	..	..	..	..	..
210	..	..	3	..	..	..	..	..	..	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..
211	..	..	3	..	..	..	..	..	..	1	..	..	..	..	..	1	..	..	..	..	..	..	..	..
212	..	..	3	..	..	..	..	..	..	..	1	..	..	..	..	1	..	..	..	..	..	..	..	..
213	..	..	3	..	..	..	..	..	1	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..
214	..	..	3	..	..	..	..	..	1	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..
215	..	..	3	..	..	..	..	..	..	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..
216	..	..	3	..	..	..	..	..	..	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..
301	..	..	3	..	..	..	..	..	..	..	1	..	..	1	..	..	..	..	..	..	..	..	..	..
302	..	..	3	..	..	..	..	..	..	..	..	1	..	1	..	..	..	..	..	..	..	..	..	..
			93	18	3	4	4	2	5	4	6	11	1	11	1	25	1	3	1	1	1	2	1	1

Quantity Sheet, Window Hardware

	W 30	W 31	W 32	W 33	W 34	W 35	W 36	W 37	W 38	W 39	W 40	W 41	W 42			W 50	W 51	W 52	W 53
51	1	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
52	1	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
53	1	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
54	1	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
55	1	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
56	..	4	..	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
57	..	4	..	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
58	1	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
59	1	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
60	1	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
61	1	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
62	1	..	..	1	..	..	..	1	..	..	..	..	..	..	..	..	..	..	..
150	..	..	..	No Hardware				..	..	Feet	..	..	..	..	..	..	..	..	..
151	..	..	..	No Hardware				..	..		..	..	..	..	..	..	..	..	..
152	Pairs	..	..	No Hardware				..	..		..	..	..	..	..	..	..	..	..
153		..	..	No Hardware				..	..	..	..	..	..	..	..	..	..	..	..
154		4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
155		..	..	..	6	1	2	..	..	..	..	..	..	..	..	3	2	2	1
156		..	..	..	6	1	2	..	..	..	..	..	..	..	..	3	2	2	1
157		4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
158		4	..	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
159		4	..	..	..	..	..	..	1	15	4	..	..	..	..	3	2	2	..
160		4	2	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
161		4	2	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
162		4	2	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
163		4	2	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
164		4	2	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
165		4	2	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
166		4	2	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
167		4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
168		4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
169		4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
170		4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
250		4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
251		4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
252		4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
253		4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
254		4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
255		4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
256		4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
257		4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
258		4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
259		4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
260		4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
261		4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
262		4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
263		4	2	..	..	..	..	..	1	15	4	1	..	..	..	3	2	2	1
351		4	..	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
352		4	..	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
353		4	..	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
354		4	..	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
355		4	..	..	..	..	..	..	1	15	4	1	..	..	..	..	..	..	..
356		4	..	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
357		4	..	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
358		4	..	..	..	..	..	..	1	15	4	..	..	..	..	..	..	..	..
	10	156	54	10	12	2	4	10	39	585	156	21	1	..	..	69	46	46	22

Same as D 4

4 for general use

Quantity Sheet, Miscellaneous Hardware

	*M*60	*M*61	*M*62	*M*63	*M*64	*M*65	*M*66	*M*67	*M*68	*M*69	*M*70	*M*71	*M*72
90	....	....	4	....	....	....	....	....	....	1	....	....	....
91	3	....	....	12	....	....	....	....	....	..	....	....	....
190	....	....	....	....	1	1	3	2	....	....	....	....	....
191	....	....	....	....	1	1	....	2	....	....	....	....	....
192	....	....	....	....	1	1	3	2	....	....	....	....	....
193	....	....	....	.:..	1	1	3	2	....	....	....	....	....
194	....	....	....	....	2	2	....	4	....	....	....	....	....
195	....	....	....	....	1	1	4	2	....	....	1	....	....
290	4	....	6	....	....	....	....	....	....	1	....	....	....
291	....	....	....	....	....	....	3	....	Pairs	....	Pair	....	....
292	....	....	....	24	....	....	....	....	....	....	....	....	....
293	....	2	....	30	....	....	....	Pairs	....	....	....	....	....
294	....	2	....	30	....	....	....	....	....	....	....	....	....
295	....	....	....	....	....	....	....	....	3	....	....	9:0	3
296	....	2	....	30	....	....	....	....	....	....	....	....	....
297	....	2	....	30	....	....	....	....	....	....	....	....	....
	7	8	10	156	7	7	16	14	3	2	1	9:0	3

Based on the foregoing memoranda and quantity sheets, we are now prepared to make out a list covering every detail of hardware required, and to submit same for quotation of prices. This list, with prices current in normal times, for *cheap*, *medium*, and *best* grades of hardware will assume substantially the form of one of the following bills:

BILL No. 1

Bill for the Cheapest Grade of Hardware which under any Conditions would be Suitable

DOORS

				PRICE
*D*3	93, 4x4 in. wrought-iron japanned loose-pin butts, 5 knuckles, with tips on pins; 47 pairs	@	$0.18	$ 8.46
*D*4	18, 5x5 in. butts, same as above; 9 pairs	@	.30	2.70
*D*5	3 Pairs 14 in. plain tee-hinges	@	.20	.60
*D*6	4 R. H. plain knob latches, brass front, and strike-plate, all interior works of brass or bronze	@	.80	3.20
*D*7	4 L. H. latches same as above	@	.80	3.20
*D*8	2 R H cylinder latches with flat pass key and stop-work (works same as above)	@	4.00	8.00
*D*9	5 R. H. latches with thumb-bolt (works same as above)	@	1.00	5.00
*D*10	4 L. H. latches with thumb-bolt (works same as above)	@	1.00	4.00

*D*11	6	R. H. latches, dead-bolt, with three tumblers and bit key (works same as above)	@ 1.00	6.00
*D*12	11	L. H. latches, dead-bolt, with three tumblers and bit key (works same as above)	@ 1.00	11.00
*D*13	1	Sliding-door latch, all brass or bronze except case	....	2.15
*D*14	11	Mineral door-knobs, round, iron escutcheons, common spindles	@ .10	1.10
*D*15	1	Heavy japanned iron store-door latch with thumb-piece	....	.20
D16	25	Pairs jet knobs, with 23 pairs plain bronze-plated escutcheons approximately 1½x5½ in. @ 34c ...	7.82	
		and 2 pairs solid bronze similar escutcheons, 1 pair for front vestibule door, and 1 only for outside of 2nd vestibule door and back hall door @ 81c	1.62	9.44
*D*17	1	2½-in. Padlock and hasp, all iron except interior of padlock, which is to be of brass and to have three tumblers; also chain for securing padlock when not in use	....	.40
*D*18	3	Chain-bolts, plain wrought iron, bronze-plated	@ .60	1.80
*D*19	1	Set sliding-door hanger and track, with 5-in. iron anti-friction wheels	....	4.00
*D*20	1	Refrigerator clamp, cast-iron galvanized, 6-in. lever handle with 6-in. bolt	....	.40
*D*21	1	Pair 6-in. japanned iron double-acting spring butts	....	1.75
*D*22	2	Push-plates approximately 3x12 in., wrought-iron, bronze-plated	@ .40	.80
*D*23	1	Heavy iron 6-in. bolt	....	.15
*D*24	1	Solid bronze, plain electric bell push-button	....	.20
			Total cost for doors	$ 74.55

WINDOWS

*W*30	10	Pairs 3x3 in. fast-pin plain iron butts	@ $0.06½	$ .65
*W*31	156	Window pulleys, wheel 2-in. on running face, steel pin and bushing, wheel and face iron, 13 doz	@ 1.00	13.00
W32	54	Hook-pattern sash-lifts at least 1⅜x1¾ in. bronze-plated iron, 4½ doz	@ .28	1.26
W33	10	Heavy cellar-window fasteners, combined with pull, japanned iron	@ .08	.80
*W*34	6	Pairs 5x5 in. loose-pin butts (same as *D* 4)	@ .30	1.80
*W*35	2	L. H. French window latches with lever handle (similar throughout to No. 7, except that in depth they are to be no more than 1½ in)	@ .60	1.20
*W*36	4	Flush bolts with knob or lever operating device, 12 in. long, bolt ⅝ in. in diameter, all visible parts iron, bronze-plated	@ 40	1.60

W37	10	Wire hooks and eyes, 4 in. long, wire not less than ⅛ in. in diameter (No. 11 gauge)	@	.02	.20
W33	39	Sash-locks, approximately 2½x2¼ in., iron, japanned, with horizontal action and of such design that sash will be drawn ¼ in., 3¼ doz	@	1.00	3.25
W39	600	feet ¼ in. braided (white) cotton sash-cord, 13 lbs.	@	.30	3.90
W40	156	Sash-weights (iron), approximately 1,800 lbs	@	.01¾*	31.50
W41	21	Flush sash-sockets, 1 in. diameter, iron, 1⅔ doz	@	.25	.44
W42	4	Pull-down hooks, bronzed iron, mounted on poles 5 feet long	@	.40	1.60
W50	69	Pairs wrought-iron blind hinges	@	.09	6.21
W51	46	Wrought-iron blind fasteners, 3⅛ doz	@	.50	1.92
W52	46	Iron blind catches for sill, 3⅝ doz	@	.12	.46
W53	22	Sets blind adjusters,** rods not less than $\frac{5}{16}$ in. in diameter, which will hold the blind open at any angle up to 60° from the house, 1⅝ doz		3.50	6.42
		Total cost for windows			$ 76.21

MISCELLANEOUS HARDWARE

M60	7	Towel hooks, japanned iron, projection 6 in.	@	$0.15	$ 1.05
M61	8	Coat " " " " 6 in.	@	.15	1.20
M62	10	Wardrobe " " " " 3½ in.	@	.03	.30
M63	156	Wire closet hooks, $1\frac{1}{12}$ gross	@	.90	.98
M64	7	Knee-catches, iron, japanned, plate on door approximately 1x2 in.	@	.06¼	.44
M65	7	Cupboard spring catches round or T-handles, base not less than 2x2 in., japanned iron	@	.25	1.75
M66	16	Plain iron drawer-pulls, japanned, not less than 4 in. long, *one* to be used on each drawer, also one on flour-box, 1⅓ doz	@	.40	.54
M67	14	Pairs 3x3 in. loose-pin butts with tips, japanned iron, 2 to each cupboard door	@	.08	1.12
M68	3	Pairs 2x2 in. fast-pin butts, iron (drop-front drawers)	@	.05	.15
M69	2	Toilet-paper holders, nickel-plated, to hold rolled paper, and of heavy plain pattern	@	.30	.60
M70	1	Pair heavy iron pivots for flour-box	@	.15	.15
M71	9	feet of light brass chain, for holding in horizontal position drop fronts of drawers	@	.01½	.14
M72	3	Flush-ring cupboard catches for closing drop fronts to drawers	@	.30	.90
		Total cost for Miscellaneous Items			$9.32

*NOTE.—The price of sash-weights varies materially in different localities, depending on local facilities for casting them.

**NOTE.—If of a type combining sill catch for securing blinds when shut, *W52* can be dispensed with; but under any circumstances *W51* will be required.

Summary

Hardware for Doors	$ 74.55
" " Windows	76.21
" " Miscellaneous Items	9.32
Total cost for cheapest grade of hardware suitable	$160.08

The hardware items listed in the above bill are all of a substantial character, but of such grade that at no point is money expended for the sake of appearances. The total cost, $160.08, is certainly a very low amount to expend for hardware in a home of this character. In several points, accordingly, changes from the above list can be made with advantage, as follows:

BILL No. 2

Hardware of Middle Grade in Every Respect Suitable

DOORS

*D*3	All butts for second story changed to a good quality bronze-plated butts, making these items:			
	35 Pairs, unchanged	@ $0.18	....	$ 6.30
	12 Pairs, changed	@ .43	....	5.16
*D*4	9 Pairs, changed to finish as above	@ .57	....	5.13
*D*5, *D*6, *D*7, *D*8, *D*9, *D*10, *D*11, *D*12, *D*13, *D*14, *D*15,	price unchanged		....	44.45
*D*16	23 Pairs of jet knobs changed to spun or wrought metal, escutcheons not changed but with *screwless spindles*	@ .86	....	19.78
	2 Pairs changed to cast bronze knobs to go with bronze escutcheons (outside doors)	@ 1.50	...	3.00
*D*17, *D*18, *D*19, *D*20, *D*21,	unchanged		....	8.35
*D*22	Bronze push-plates in lieu of bronzed iron (for wearing qualities only), 2	@ .60	....	1.20
*D*23	Unchanged		....	.15
*D*24	One solid bronze electric bell push-button with face-plate 2 in. x 4 in		....	.50
	Total cost for Doors			$ 94.02

WINDOWS

*W*30, *W*31, *W*32, *W*33,	unchanged		....	$ 15.71
*W*34	Changed same as *D*4, 6 prs	@ $0.57	..	3.42
*W*35	Unchanged		....	1.20
*W*36	Flush-bolts changed to bronze, 4	@ 1.35	....	5.40
*W*37, *W*38, *W*39, *W*40,	unchanged		....	38.85
*W*41	21 Sash sockets changed, 1 in. x 2 in. bronzed iron	@ .50 doz.		.88
*W*42, *W*50, *W*51, *W*52, *W*53,	unchanged		....	16.61
	Total cost for Windows			$ 82.07

MISCELLANEOUS HARDWARE

*M*60, *M*61, *M*62, *M*63, *M*64, unchanged			....	$ 3.97
*M*65	7 Cupboard spring catches, changed to bronzed iron (same price as japanned),	@	.25....	1.75
*M*66	16 Drawer-pulls, changed to bronze-plated	@	.60 doz.	.80
*M*67	14 Pairs 3 in. x 3 in. loose-pin butts, changed to bronze-plated	@	.18....	2.52
*M*68, *M*69, *M*70, *M*71, *M*72, unchanged			....	1.94
	Total Cost for Miscellaneous Items			$ 10.98

Summary

Hardware for Doors	$ 94.02
" " Windows	82.07
" " Miscellaneous items	10.98
Total cost for hardware of middle grade in every respect suitable	$187.07

If it is desired to place the *best hardware* which is in any way suitable for the dwelling under consideration, a bill along the following lines would be made up (not duplicating the detail of the first or second bills where unchanged):

BILL NO. 3

Hardware of Best Grade

DOORS

*D*3	All butts in second story changed to the best quality of bronze-plated or wrought-bronze, ball-bearing 12 pairs	@	$0.62....	$ 7.44
	Unchanged, 35 pairs	@	.18....	6.30
*D*4	9 Pairs changed to finish same as above	@	.75....	6.75
*D*5, *D*6, *D*7, *D*8, *D*9, *D*10, *D*11, *D*12, *D*13, *D*14, *D*15, unchanged			....	44.45
*D*16	23 Pairs of knobs and escutcheons, changed to cast metal	@	1.50....	34.50
	2 Pairs not changed from Bill No. 2		....	3.00
*D*17, *D*18, Unchanged			....	2.20
*D*19	One set sliding-door hangers, changed to ball-bearing		....	5.50
*D*20	One refrigerator clamp, changed to brass		....	.75
*D*21	One spring double-acting hinge unchanged		....	1.75
*D*22, *D*23, *D*24, unchanged from Bill No. 2			....	1.85
	Total Cost for Doors			$114.49

WINDOWS

*W*30	Unchanged		....	$ 0.65

W31	156 Window pulleys, changed to bronze face and wheel, roller-bearings, 13 doz.	@ 4.60 doz.	59.80
W32	54 Flush bronze sash-lifts, 3 in. x 1⅛ in.	@ .60 doz	2.70
W33	Same as in Bill No. 1	....	.80
W34	6 Pairs, changed to best-quality bronze-plated or wrought bronze, ball-bearing	@ .75....	4.50
W35	Unchanged	....	1.20
W36	" from Bill No. 2	....	5.40
W37	" " " " 1	....	.20
W38	39 Solid bronze sash-locks, 3½ doz.	@ 4.00....	13.00
W39	600 Feet sash chain in lieu of cotton cord	@ .02½...	13.50
W40	Unchanged from Bill No 1	....	31.50
W41	21 Sash sockets, same as in Bill No. 2	....	.88
W42	4 Bronze pull-down hooks polished poles	@ 1.00....	4.00
W50, *W51*, *W52*, *W53*, unchanged		....	15.01
	Total Cost for Windows		$153.14

MISCELLANEOUS HARDWARE

M60, *M61*, *M62*, *M63*, *M64*, *M65*, *M66*, *M67*, *M68*, *M69*, *M70*, *M71*, *M72*, unchanged from Bill No. 2		....	$10.98

Summary

Hardware for Doors	$114.49
" " Windows	153.14
" " Miscellaneous Items	10.98
Total Cost for Hardware of Best Grade	$278.61

By comparing the figures of these three bills, it will be seen that the price varies as follows:

Bill No. 1—Very plain but thoroughly substantial hardware	$160.08
Bill No. 2—Varying from the above by using more ornamental fixtures	187.07
Bill No. 3—By using the best material and appliances appropriate	278.61

Attention is very particularly directed to the fact that none of the bills call for designs with other than *plain surfaces*. For general use, where the best results from all points are desired, the scheme on which Bill No. 2 is based is by far the best. Few persons would ever notice a difference between schemes No. 2 and No. 3, although the latter costs nearly 50 per cent more than the former.

REVIEW QUESTIONS

REVIEW QUESTIONS

ON THE SUBJECT OF

HEATING AND VENTILATION

PART I

1. What advantage does indirect steam heating have over direct heating? What advantages over furnace heating?

2. What are the causes of heat loss from a building?

3. Why is hot water especially adapted to the warming of dwellings?

4. What proportion of carbonic acid gas is found in outdoor air under ordinary conditions?

5. A room in the northeast corner of a building of fairly good construction is 18 feet square and 10 feet high; there are 5 single windows, each 3 by 10 feet in size. The walls are of brick 12 inches in thickness. With an inside temperature of 70 degrees, what will be the heat loss per hour in zero weather?

6. State four important points to be noted in the care of a furnace.

7. A grammar school building, constructed in the most thorough manner, has 4 rooms, one in each corner, each being 30 ft. by 30 ft. and 14 ft. high, and seating 50 pupils. The walls are of wooden construction, and the windows make up $\frac{1}{3}$ of the total exposed surface. The basement and attic are warm. How many pounds of coal will be required per hour for both heating and ventilation in zero weather, if 8000 B.t.u. are utilized from each pound of coal?

8. What two distinct types of furnaces are used? What are the distinguishing features?

9. What is meant by the efficiency of a furnace? What efficiencies are obtained in ordinary practice?

10. What patterns of valves should be used for radiators? What conditions of construction must be observed in making the connections between the radiator and riser?

11. The heat loss from a shop is 36,000 B.t.u. per hour; how many linear feet of 2-inch pipe will be required to warm it, using low-pressure steam?

REVIEW QUESTIONS

ON THE SUBJECT OF

HEATING AND VENTILATION

PART II

1. How would you obtain the sizes of the cold-air and warm-air pipes connecting with indirect heaters in dwelling-house work?

2. What is an aspirating coil, and what is its use?

3. What efficiencies may be allowed for indirect heaters in schoolhouse work? How would you compute the size of an indirect heater for a room in a dwelling-house?

4. How is the size of a direct-indirect radiator computed?

5. A schoolroom on the third floor is to be supplied with 2400 cubic feet of air per minute. What should be the area of the warm-air supply flue?

6. What is the chief objection to a mixing damper, and how may this be overcome?

7. How many square feet of indirect radiation will be required to warm and ventilate a schoolroom when it is 10 degrees below zero, if the heat loss through walls and windows is 42,000 B.t.u., and the air supply 120,000 cubic feet per hour?

8. What is the difference in construction between a steam radiator and one designed for hot water? Can the steam radiator be used for hot water? State reasons for answer.

9. How may the piping in a hot-water system be arranged so that no air-valves will be required on the radiators?

10. What efficiency is commonly obtained from a direct hot-water radiator? How is this computed?

11. How should the pipes be graded in making the connections with indirect hot-water heaters? Where should the air-valve be placed?

12. Describe briefly one form of grease extractor.

13. What is the office of a pressure-reducing valve in an exhaust-steam heating system?

14. Upon what principle does a pump governor operate?

REVIEW QUESTIONS

ON THE SUBJECT OF

STEAM AND HOT WATER FITTING

1. What points should be borne in mind when selecting a heating boiler for a given service?

2. Explain by an example how to check the catalogue rating of a boiler.

3. Point out the difference between (a) direct, (b) direct-indirect, and (c) indirect radiation.

4. State the advantages of each type.

5. What advantages do overhead coils possess over other classes of direct radiation?

6. (a) With overhead coil heating, how should the coils be placed with reference to walls and floor to secure the best results? (b) Why?

7. In what two ways is heat given off by a radiator?

8. What advantages has a wet return system over one with dry returns?

9. (a) In what classes of buildings, as a rule, may the overhead feed system be used and why? (b) What advantages are possessed over the up-feed system?

10. When should a two-pipe system be used in preference to a one-pipe?

11. Explain the action of a siphon trap in balancing a low pressure steam heating system.

12. When is it advisable to establish an artificial water line?

13. Explain in detail how to compute the radiating surface for low pressure steam in a corner room 18 ft. square, 10 ft. high, the exposed wall to be 16 in. thick, exposed toward the north and west, and having glass surface equal to one-fourth the total exposed surface of wall and glass combined.

14. Describe the action of aspirating heaters. To be most effective in causing a rapid flow of air in a flue, at what point should they be placed?

REVIEW QUESTIONS

ON THE SUBJECT OF

SANITARY APPLIANCES

1. How can the water seal of a trap be broken by siphonage?

2. Define a mechanical trap and state the advantages it possesses over the ordinary type.

3. What are the essential features of a good bathtub?

4. Which do you prefer for the ordinary type of residence, a solid porcelain or an enameled-iron bathtub?

5. Mention three types of water closets which are better than the hopper and say why they are superior.

6. Which do you prefer, a high or a low tank, to supply a water closet?

7. Sketch and describe a good form of range closet.

8. Sketch, in section, a good form of flushometer.

9. Describe the different types of drinking fountains and their use.

10. What, in your opinion, is the best material for lavatory basins?

11. How are the effects of grease in sink water avoided?

12. How is the flushing of urinals effected?

13. Sketch and describe a good type of pantry sink.

14. In what respect does a slop sink differ from a kitchen sink.

15. Sketch two laundry tubs of modern pattern and show the necessary waste and vent pipes.

REVIEW QUESTIONS

ON THE SUBJECT OF

WATER SUPPLY

PART I

1. How does the use of water vary month by month and day by day?

2. How do surface and ground waters compare generally as to quality?

3. What is a fair amount of water consumption per capita for various purposes?

4. If rain is falling at the rate of 4 inches per hour and the run off is one-half as fast, what will be the flow in cubic feet per second from a drainage area of 10 square miles?

5. If the least annual run-off of a drainage area of 10 square miles be equal to 8 inches in depth, how many people will this provide for if the consumption averages 100 gallons per head per day, assuming there is storage capacity sufficient to utilize all the run-off for the year?

6. What storage capacity will be required in the above case if all the 8 inches runs into the reservoir in 5 months, leaving 7 months' demand to be met from the reservoir?

7. What conditions make it possible to secure artesian wells?

8. In what sort of material are we likely to find the most ground water available?

9. About what rate of consumption for fire purposes would be expected in a city of 25,000 inhabitants?

10. What causes the occurrence of springs?

11. What causes water to flow through the ground?

12. What are the most important uses of a public water supply?

13. What are the advantages and disadvantages of timber dams?

14. What considerations determine the location of lake and river intakes?

15. What is the purpose of core walls and how are they made?

REVIEW QUESTIONS

ON THE SUBJECT OF

DRAINAGE WORK AND VENTING

1. Give the relative advantages and disadvantages of the house trap on a drainage system.

2. Would a gradient of 1 in 5 be satisfactory for a drain 4 inches in diameter? Assuming that it is compulsory to lay the drain at this pitch, tell what precautions you would take to insure thorough cleansing.

3. You are called to a house to inspect the drainage system which has been installed thirty years. Mention the defects likely to be found and quote your recommendations.

4. How are drains tested? Describe all the tests you are familiar with.

5. A customer purposes building a house in an isolated country district remote from all habitation. Sketch neatly and give a full description and specifications of the system you would recommend to satisfactorily dispose of the sewage.

6. How can the flooding of basements, caused by back pressure, be obviated?

7. Sketch the three recognized systems of carrying out drainage work.

8. Which kind of pipe do you prefer for a drain under the house: cast iron, wrought iron, or vitrified clay? Give the reasons for your selection.

9. How should soil, waste, and vent pipes be installed in buildings to take care of condensation?

10. When a house is to be unoccupied during cold weather, what should be done to prevent the traps from freezing?

REVIEW QUESTIONS

ON THE SUBJECT OF

DOMESTIC HOT-WATER SUPPLY

1. Define conduction, radiation, and convection.

2. What causes hardness in water, and what material will prevent this lime or incrusted deposit taking place?

3. Mention all the types of heaters with which you are familiar. State when you would recommend each type.

4. Is there any material difference between the street pressure and the gravity systems of supply? Make a sketch of each.

5. What do you understand by the term *secondary circulation?* When and where would you adopt it?

6. Why is it necessary to use an expansion pipe with a gravity supply and not with a street pressure supply?

7. What size of circulation pipes would you use with a temporary hard-water supply?

8. Mention the material you would use for the entire apparatus with soft water, temporary hard water, or permanently hard water.

9. Is there any system you could furnish to obviate all nuisances from a temporary hard-water supply?

10. Discuss the advantages and disadvantages of the double-boiler system of supply.

11. When and where would you use a steam coil? What advantage does it possess over other methods?

12. When would you recommend instantaneous gas heaters as the best method of supply?

13. Show by a sketch how you would connect three heaters to one large boiler.

REVIEW QUESTIONS

ON THE SUBJECT OF

HARDWARE

1. What is the difference between a *hinge* and a *butt?*

2. What hardware attachments are desirable when outside window blinds are used?

3. What is the difference between a *lock*, a *latch*, and a *bolt?* How is a latch sometimes made to serve the purpose of a lock? What is a *dead bolt?*

4. What is the difference between a right-hand and a left-hand door?

5. How are door knobs prevented from getting loose?

6. What is meant by *flush* hardware? Give instances of its use. Illustrate, if possible, with diagrams.

7. What are the essential features of a good type of escutcheon?

8. Write a brief historical sketch of the development of the common nail.

9. Describe the different kinds of nails now in common use, noting their relative advantages for different kinds of work and the precautions that should be taken in driving them.

10. Describe the two main classes of locks, with a diagram illustrating each.

11. If you were asked to inspect the window-sash hardware in an up-to-date modern dwelling-house, make out a list of the items you would look for.

12. In joining woodwork, what method is sometimes adopted to overcome the effects of shrinking and swelling?

13. Discuss, giving diagrams, the possibility of the artistic use of strap hinges and tee-hinges.

14. Describe the different classes of door butts, and compare their advantages.

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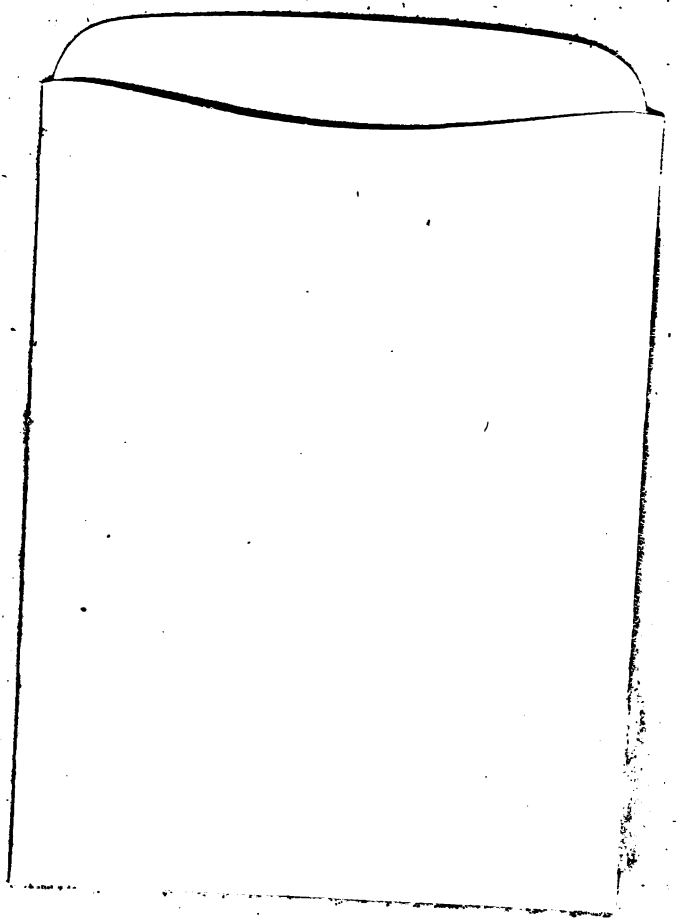
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